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(*Paper No. 2318.*)

# "Compressed Oil-Gas and its applications."

By ARTHUR AYRES, M. Inst. C.E.

IN considering this system of illumination, its applicability to buoys, isolated beacons, lighthouses, railway-carriages, &c., it is proposed to treat it under the primary heads of mode of manufacture, illuminating properties, cost, storage, transit; and in doing so to refer briefly to the early history of oil-gas, and to the patents taken out from time to time in connection with the system. In 1825 Faraday contributed a Paper to the Royal Society "On New Compounds of Carbon and Hydrogen, and on certain other products obtained during the decomposition of Oil by Heat."[1] In this communication the chemistry of oil-gas is dealt with, which it is not proposed to consider in the present Paper. It was stated that 1,000 cubic feet of good gas yielded nearly 1 gallon of hydrocarbon. The gas from which the hydrocarbon was obtained was manufactured by the Portable Gas Company and was compressed to 30 atmospheres. It was drawn from a gasholder and passed over water into a large and strong receiver, and from it into portable vessels, the principal condensation taking place in the receiver. The oil-gas manufactured by the Portable Gas Company was not distilled from shale-oil or petroleum, but from other oils and fatty substances, mineral or vegetable.[1]

In 1792 Murdock compressed coal-gas and used it as a substitute for lamps and candles.

In 1815, Mr. John Taylor, of Stratford, Essex, took out a patent entitled, "The Manufacture of Gas," which described an apparatus

[1] Phil. Trans. Royal Society of London, 1825, p. 440; and Philosophical Magazine, vol. lxvi. p. 180.

for producing inflammable gas of great brilliancy from vegetable or mineral oils and other substances. The apparatus consisted of a funnel or receptacle for the oil in conjunction with two cast-iron pipes, or retorts, which were attached to a chamber for receiving the refuse. These pipes were heated in a fireplace, into which they were built. The oil, on being admitted into the first pipe, or retort, was converted into gas, which was further distilled by ascending the second pipe, through which it passed on its way to the gas-holder. This system, in a general way, rudely resembled, but was of course not so perfect in its details as, the apparatus at present in use for the manufacture of oil-gas.

Many other patents in this connection have from time to time been granted, thus:—

In 1819, to Messrs. David Gordon (of Edinburgh) and Edward Heard (of Brighton) for compressing gas by a force-pump into a receiver. The gas so compressed was described as being portable, and capable of being placed under the seats of carriages, or being used on board ships.

In 1837, to Mr. Henri Quinten Tenneson, late of Paris, entitled, "Apparatus for containing and Compressing Portable Gas." It included the employment of a number of small cast-iron receivers, which were capable of being removed when charged, and replaced at pleasure to be re-charged. The gas was delivered into these receivers from an intermediate receptacle, under pressure, and was compressed by heat instead of by force-pumps, as now adopted. There were three regulators, two for high-pressure oil-gas, and one for low-pressure or ordinary coal-gas, for regulating the supply of gas, and the pressure at the burner. The first of these consisted of a cylindrical metal box, fitted with a diaphragm attached to a lever acting upon a horizontal valve-rod and valve, the lever having an adjustable weight at its outer end for balancing the parts. The second regulator differed but little from the first in action, the valve and valve-rod operating vertically instead of horizontally, and the lever being balanced by a spiral spring, instead of by an adjustable balance weight, as in the former regulator. The valve-seats were made of agate or hard steel. The function of these two regulators is as follows: the gas being admitted into the gas-chamber causes the flexible diaphragm to rise, carrying with it the valve-rod and valve; while the gas is passing from the receiver into the regulator, it is drawn off by a pipe leading to the burner, where it is consumed as fast as supplied. The diaphragm and lever remain inoperative, so long as the pressure is constant, but when the supply

of gas exceeds the consumption, or when from any cause an increase of pressure takes place within the regulator, the gas therein acting against the large surface of the diaphragm raises it, giving motion to the valve-rod, and forcing the valve into the inlet aperture; the supply of gas is thus restricted, but not wholly suppressed. Should the pressure of the gas become very great, increased motion would be imparted to the valve-rod and valve, entirely suppressing the inflow of the gas until the pressure was reduced by its consumption at the burner. The pressure upon the diaphragm being thus relieved, the diaphragm is drawn down by the lever and spring, or weight, thus re-opening the inlet aperture and admitting a fresh supply of gas into the regulator. This action is repeated with the variation of pressure. A description of the third, or water-regulator, is unnecessary, being intended for low-pressure or ordinary coal-gas.

In 1873, to Mr. John Mewburn, acting as agent to Mr. Julius Pintsch, of Berlin, for "Lighting Railway-Carriages" separately, also a regulator or governor.

In 1874, to Mr. James Keith, of Arbroath, N.B., for improvements in the "Manufacture of Illuminating Oil-Gas and in the apparatus employed therein." This system does not differ essentially from those of Pope and Pintsch; it will be referred to further on.

In 1876, to Mr. Charles Denton Abel, as agent for Mr. Julius Pintsch, for "Improvements in Floating Lights, and in apparatus for the same." This patent referred to the illumination of buoys by compressed oil-gas, and included a cylindrical lantern of special construction with double glazing for excluding wind and rain, also a special regulator and gas-burner applicable to gas-buoys.

In 1880, to Messrs. George and Anthony Bower, of St. Neot's, for "Improvements in Lighting with Compressed Gas, and in the apparatus employed therein, especially applicable to carriages, ships, buoys, and isolated buildings." This patent included a balanced regulator, and an apparatus for carburetting common gas of low illuminating power, applicable to railway-carriages. It consisted of a rectangular box of cast-iron containing two wrought-iron hinged flaps, with leather diaphragms attached thereto. These flaps were connected by an arrangement of levers to a valve-rod and valve. The gas, entering through a valve into the chamber, acted upon the flaps, forcing them outwards, as the pressure of the gas within the regulator increased, and, through the intervention of the levers, closed the inlet valve; thus suppressing the inflow of the gas to the regulator and regulating the

supply and pressure at the burners. One of these regulators is in use at Broadness Lighthouse, and is found to work satisfactorily.

In 1880, to Mr. Alexander Pope, of Slough, for the "Heating and Lighting of Railway Carriages, and for similar purposes." This patent embraced the manufacture of gas from petroleum oil, either alone, or mixed with coal-gas; and included a regulator, having a flexible diaphragm with the usual appendages as in the regulators of Tenneson and Pintsch.

In March, 1881, to Mr. William Robert Lake, as agent for Mr. John Melville Foster, of Philadelphia, United States of America, for "A Gas-Light Apparatus for Buoys and Lighthouses." This patent provided for the illumination, by compressed gas, of buoys, beacons, and lighthouses, automatically ignited and extinguished by clockwork; also a regulator, consisting of a chamber fitted, as usual, with a flexible diaphragm in conjunction with a volute spring for regulating the pressure of the gas at the burner. The action of this regulator also resembled those already described.

In 1883, to Mr. William B. Rickman, on behalf of Messrs. Richard and Oskar Pintsch, of Berlin, and himself, for an "Apparatus for producing Intermittent or Flashing Lights." This apparatus will be more fully referred to hereafter, in connection with the illumination of gas-buoys.

These patents, which embrace many ingenious points of detail, are too numerous to be referred to at length.

Oil-gas is the product of heavy petroleum or shale-oil once distilled; it has a specific gravity of about 0·840, more or less, and flashes at about 220° Fahrenheit.

In now detailing the process of the manufacture of oil-gas, it is proposed to describe the works which were erected for the purpose at the South Foreland by "Pintsch's Patent Lighting Company, Limited," and used in the recent experiments on lighthouse illuminants, which works were subsequently purchased and re-erected by the Honourable Corporation of Trinity House at Blackwall, for the service of their gas-buoys and beacons (Plate 5). The works consist of a retort-house, a purifying and meter-house, a gasholder and an engine-room. The retort-house contains two furnaces, and four cast-iron retorts set in pairs, in brickwork, in the usual manner; with a central chimney, a hydraulic main or receiver for the gas, a cistern for oil with hand-pump, and a set of water-gauges to show the pressure of the gas in its various stages of distillation, until delivered into the gasholder. The purifying house contains an air-condenser or cooler, a washer and lime purifier, and a mèter. In the engine-room there is a small hori-

zontal high-pressure steam-engine, supplied with steam at a pressure of 40 lbs. per square inch from a boiler situated on the premises, and a double-acting force-pump for compressing the gas.

The oil from which the gas is made is stored in a tank sunk in the ground outside the retort-house.

A hand-pump is fixed in the retort-house, with its suction pipe let into the oil-tank. This pump delivers the oil into a small cistern placed on the top of the retort bench. A pipe conveys the oil from the cistern to the back ends of the upper retorts, *i.e.*, the ends farthest from the furnaces, where it is delivered by means of micrometer valves into two small funnels and inverted siphons, through which it passes directly into the retorts. The inverted siphons form seals against the pressure of the gas in the retorts. When the oil enters the retorts it is received on sheet-iron trays, along which it runs to the front of the upper retorts. It then descends through pipes into the lower retorts, in which there are no trays; thence to the back ends, by which time it is changed into a dense yellow vapour, which passes downwards into the hydraulic main, or box, containing water, where it is partially washed, and where a large portion of the tar is deposited. From this the gas and most of the tar pass on to the condenser; but, before entering it, the tar overflows from a trap into a pipe leading to a tank sunk in the ground outside the retort-house. This overflow affords a convenient means of ascertaining whether the oil has been sufficiently vaporized, a small quantity of the tar being placed upon a piece of white paper for the purpose. If a strongly-marked greasy border be observed on the paper, either the supply of oil must be reduced where it enters the retorts; or it may be that the retorts are not sufficiently heated, in which case the heat must be increased in order that the proper quantity of oil may be converted into gas. This test shows when the oil and heat are properly regulated, as, when such is the case, no greasy mark will be noticeable on the paper. The condenser is simply a close cylindrical vessel of cast-iron, 8 feet high by 2 feet 4 inches in diameter, placed on end. The inlet pipe enters at the bottom, and discharges nearly at the top. The gas in passing through the condenser deposits a further quantity of tar, which collects at the bottom of the condenser, and travels through an inverted siphon, or trap, into a pipe leading into a tar-tank. After leaving the condenser the gas enters the purifier, which is a cylindrical vessel, 3 feet in diameter by 2 feet 6 inches high. The lower portion contains water, through

which the gas is passed to cleanse it from the remaining impurities. An overflow pipe inside maintains the water at the proper level. On leaving the water the gas issues upwards through two perforated trays, on which is spread a mixture of lime and sawdust. These arrangements complete the purifying process. The gas then passes on to the meter and thence to the gasholder, which is 15 feet in diameter by about 10 feet high, having a capacity of 1,800 cubic feet.

In the manufacture of oil-gas, constant and careful watching is required. The heat must be uniformly maintained, the supply of oil regulated as required, and the water-gauges observed to detect any symptom of choking about the retorts; for if, by any chance, the passages become choked by tar, or otherwise, the pressure will at once rise, and possibly become dangerous. Each pair of retorts is fitted with a gauge, showing the pressure inside, and other gauges indicate the pressure in the condenser, purifier, meter, and gasholder. When everything is in proper working order, there should be a water-pressure of 5 or 6 inches in the retorts, gradually diminishing in other parts of the apparatus to about 1½ inch in the gasholder. After the retorts have been properly heated, gas is made at the rate of 6½ to 7 cubic feet per minute. The quantity produced in one day's working, including the time required for heating the retorts (about six hours), is about 2,500 cubic feet, or 210 cubic feet per pair of retorts per hour. The quality of the gas depends more upon the temperature at which it is distilled than upon the quality of the oil.

Two of the portable gasholders employed for filling the buoys can be charged to 10 atmospheres in one day's working, gas being made at the same time to keep up the supply, from 1 atmosphere to 2 atmospheres generally remaining in the gasholders after charging the buoys.

The illuminating intensity of oil-gas may be taken at from 40 to 50 candles when burned in a London standard Argand burner, with a consumption of 5 cubic feet per hour at a water-pressure of 0·5 inch. The price varies from about 5*s.* 6*d.* to 16*s.* per 1,000 cubic feet, being directly influenced by the quantity of gas produced, the management of the retorts, and the price of oil, fuel, and wages. Where the demand is great the cost of production is correspondingly low, an important saving being thus effected, in consequence of the large amount of heat retained from one day's working to another. Taking these circumstances into account, it is evident that, where only small quantities are produced, no fair comparison can be made. Oil-gas, like ordinary coal or

cannel-coal-gas, suffers a loss of about 20 per cent. of its illuminating intensity when compressed to 10 atmospheres, owing to the deposit of its hydrocarbon. The quantity of hydrocarbon deposited per 1,000 cubic feet of oil-gas compressed to 10 atmospheres varies, but is stated to be about 1 gallon, and the quantity of tar from 4 to 5 gallons. The value of these products varies considerably, from nothing to as much as 2*s.* 6*d.* per 1,000 cubic feet of gas. The quantity of gas produced from 1 gallon of oil is from 70 to 90 cubic feet. The gas required for buoys and beacons is compressed to about 10 atmospheres in portable steel gas-holders, 4 feet 2 inches in diameter and 19 feet long, weighing 3 tons each, having a capacity of 259 cubic feet, by the portable steam-engine and compressing pump. The pump is double-acting, 4 inches in diameter by 12 inches stroke, making about seventy to eighty effective strokes per minute. The pump-barrel and end-covers are provided with water-jackets through which a constant current of cold water is circulated to keep the pump cool. It would otherwise become heated during the operation of compressing the gas. The valves are neatly arranged in the covers, and are easy of access. The clearance between the pump-piston and the valves being as small as possible, nearly the whole contents of the pump are discharged at each stroke.

## Buoys and Beacons.

Until the adoption of oil-gas for their illumination, buoys and isolated beacons were only useful for the purposes of navigation by day; but they are now rendered equally so by night (in clear weather), enabling vessels to navigate with safety intricate channels, which hitherto could not have been attempted except at considerable risk. The great advantages secured by this addition to the existing means of coast illumination cannot fail to be of the utmost importance, and must in time be greatly extended.

Gas-buoys, as at present used by the Corporation of Trinity House, are constructed of best mild steel. They are spherical in form, 9 feet in diameter, and are surmounted by a light wrought-iron superstructure, carrying a lantern enclosing the illuminating apparatus. The total weight of one of these buoys complete is about 80 cwt., the weight of the buoy being $78\frac{3}{4}$ cwt., and that of the illuminating apparatus $1\frac{1}{4}$ cwt. The buoys are usually charged to a pressure of 5 or 6 atmospheres, or from 75 to 90 lbs. pressure per square inch. The gas is contained in the spherical portion of the buoy, the capacity of which

is about 382 cubic feet, and is consumed at the rate of 0·75 cubic foot per hour, burning night and day continuously. When fully charged to 5 atmospheres, and burning at the above rate of consumption, the light will be maintained for one hundred and six nights and days. The cost of the gas per hour depends upon the cost of production; but, taking the cost of oil-gas, as manufactured at Blackwall, at 10*s.* per 1,000 cubic feet, the cost per hour would be about 0·09*d.* The lighting apparatus consists of a group of three small fish-tail burners adapted to the above rate of consumption, and is surrounded by a small dioptric fixed lens, 100 millimetres (3·937 inches) in diameter by $4\frac{3}{16}$ inches high, embracing a vertical angle of 92°; it is composed of a central refracting belt and four rings, two above and two below the central lens. The initial intensity of the naked flame is about 5 candles, and when transmitted through the lens about 17 to 20 candles. The focal plane of the light is about 12 feet 6 inches above the sea-surface, and is visible at a distance of about 9 miles. The steadiness of the light is maintained by means of a highly sensitive automatic regulator, similar in principle to those already described. The burner, lens, regulator, and flashing apparatus, are enclosed in a specially designed cylindrical lantern with helical framing, so contrived as to exclude sudden puffs of wind, rain, and snow.

A section of the lantern and apparatus is shown by Plate 6, Figs. 3 and 4. The gas enters the regulator from the buoy by the pipe A, next passes into the flashing apparatus by the pipe D, and thence to the burner by the pipe G. Gas-buoys are made to show either fixed or flashing lights, as may be required for the purposes of distinction. The flashes are produced by an ingeniously contrived flashing apparatus, of which the following is a description.

The apparatus is worked by the gas inlet. The high-pressure gas from the buoy, after having passed the regulator, where the pressure is reduced to about 2 inches water-column, enters a round chamber covered by a diaphragm of specially prepared flexible leather; this diaphragm, on being raised by the pressure of the gas to a certain extent, communicates motion to a lever, which, assisted by a spiral spring, closes the inlet pipe, opening at the same time the passage to the burner. As the gas passes out and is consumed at the burner, the diaphragm, by its own weight, assisted by the spring, sinks, and, touching the lever, closes the outlet aperture to the burner, and at the same time opens the inlet of the gas from the buoy. Thus the light will be extinguished while the gas is entering the chamber, until, by the pressure of the gas,

the passage is again closed by the rising of the diaphragm. The light will thus continue to burn until the diaphragm again falls, and the gas within the chamber is exhausted. A small pilot jet is constantly maintained (independently of the flashing apparatus) to ensure the re-ignition of the gas when re-admitted to the burner. The number of flashes may be varied, but the usual number is about ten per minute.

The estimated cost of a first-class gas-buoy, as thus described, including the lantern and illuminating apparatus, also Royalty, is about £420. These buoys work remarkably well, and give very little trouble. Accidental extinctions have occasionally occurred through collisions, and, more frequently to the Sheerness middle buoy, by the firing of heavy ordnance at Shoeburyness.

The operation of refilling the buoys with gas is very simple. The holders charged with compressed gas, as before stated, to a pressure of 10 or less atmospheres, are conveyed to the buoy usually by a steam-tender; on arrival, connection is made between the steam-tender and the gasholder by means of a flexible tube, and communication between them thus established. As soon as the pressure is equal in the buoy and the gasholder, or as soon as the desired pressure is obtained in the buoy, the pipe is disconnected, the whole operation occupying but a few minutes after the pipe has been connected. Three of these buoys have been established in the estuary of the Thames, viz., one buoy at the East Oaze, one at the Ovens below Gravesend, and one at Sheerness Middle. Another has recently been laid at the Maplin Spit in place of the former, an ordinary conical buoy, which did not exhibit a light.

A new form of gas-buoy, as shown by Plate 6, Fig. 1, to be constructed wholly of mild steel, is about to be tried by the Trinity House; in this it is proposed to carry the gas in the lower portion of the buoy. The capacity for storage of gas will be 383 cubic feet, which, at a pressure of 5 atmospheres, will sustain the light (consuming 0·75 cubic foot per hour) for one hundred and six nights and days. The advantages of this form of buoy are improved stability, and its applicability to the recently adopted uniform system of buoyage, as the light spherical superstructure can readily be removed, and another representing the can, or cone, substituted, as shown by dotted lines. The estimated weight of this buoy is about 6 tons, without moorings.

In 1885, the Canadian Government adopted a combination of the bell-and-gas-buoy for service in the Gulf of St. Lawrence, the bell, weighing 3 cwt., giving the usual warning by day

and night, supplemented by the light. This buoy differed from those shown on Plate 6. The buoy proper, or floating portion, was 14 feet in diameter and 7 feet 9 inches from the bottom to the deck, carrying a solid welded-steel gas-holder, 12 feet high by 6 feet in diameter, and containing 339 cubic feet of gas. The buoy was surmounted by a suitable wrought-iron superstructure carrying the bell and four clappers for striking it, lantern, and illuminating apparatus. The weight of the buoy without the gasholder was 6 tons, and of the gasholder $3\frac{1}{2}$ tons, making a total weight of $9\frac{1}{2}$ tons complete. When charged to 6 atmospheres, with a consumption of gas of 0·75 cubic foot per hour, the gas was capable of maintaining the light for one hundred and thirteen nights and days, burning continuously. The illuminating apparatus consisted of a lantern, similar to that shown by Plate 6, Fig. 3, and previously described, enclosing a dioptric fixed lens, 198 millimetres (7·795 inches) in diameter, having a central belt and six refractors, three above and three below, subtending a vertical angle of 80°. The burner consisted of three jets, oval in form, each flame being $1\frac{1}{4}$ inch high by about $\frac{5}{16}$ inch wide at the centre. The intensity of the naked flame was about 6 candles, and through the lens 20 candles, as in the Trinity House buoys.

Pintsch's gas-buoys are used at the Port Said entrance and elsewhere on the Suez Canal, and other important situations. The Suez Canal Company has at the present ninety-eight lights of various kinds on Pintsch's system.[1]

In 1881 a beacon, lighted automatically by compressed oil-gas on Pintsch's system, was adopted by the Clyde Lighthouses Trustees, who have recently erected another on the Gantock Rock, off Dunoon, on the Argyleshire coast, and are extending this system of illumination at Cardross and Dumbuck lighthouses, Donald's Quay, Rashilee, and Dalmuir light-towers.

In December 1885, two iron lighthouses, similar in construction (Plate 6, Fig. 5), were erected by the Trinity House, one at Stoneness, opposite Greenhithe, on the Essex shore, and the other at Broadness, opposite Grays, on the Kentish shore of the River Thames. At Stoneness Lindberg's system was adopted, the burner for producing the light being that of Lyth, of Stockholm. The light burns day and night at full power, showing a white light with short occultation at periods of about five seconds.

[1] At the present time there are one hundred and forty-nine gas-buoys in use in various countries, as detailed in the Table, p. 312.

## STONENESS LIGHTHOUSE.

The light is produced by the combustion of a spirit of petroleum called deodorized naphtha, flashing at the ordinary temperature of the atmosphere. Two cisterns containing the spirit are placed at the rear of the lantern and within the limits of the non-illuminated arc, and a little higher than the burners, so that the spirit flows to the burner by simple gravitation. The cisterns are broad and shallow, and as the spirit is consumed, the small change which takes place in its level in the cistern does not materially affect the supply to the burner. Each cistern is fitted with a supply-pipe and burner, and both burners are used at the same time. The burners have very minute outlets, with brass plates bending over them to deflect the flames.

When these plates are hot, the spirit is vaporized or converted into gas at the instant of emission, and passing upwards over the lower or hollow side of the plates, burns in flat flames along the upper edges of the plates. The two burners are placed so that the upper edges form a right-angle in plan, and thus have the effect of showing a sensible breadth of flame when viewed within the limits of the illuminated arc. They have the further advantage of assisting each other, so that if there should be any accidental deficiency in one flame, the other helps to counteract it. On first lighting the burner, it is heated by igniting round it a small quantity of spirits of wine, but after that it is self-heating. The burner, the intensity of which is about 16 candles, is placed in the centre of a small fixed dioptric lens for fixed light, 300 millimetres (11·811 inches) in diameter, having a central refracting belt with three rings above, and three below, the intensity of the light through the lens being equal to about 60 candles. The occultations of the light are produced by the revolutions of opaque screens outside the lens. The screens are attached to a light revolving frame with a fine steel point at the top, resting in an agate cup, so as to turn with as little friction as possible. The upper portion of the frame over the flame is formed by a number of inclined radial plates, or vanes, which are acted on by the ascending current of heated air, and revolve like the vane of an ordinary smoke-jack. The periods of the revolutions, or occultations, are not capable of accurate adjustment, but do not vary much after the flames have been properly regulated. The cisterns contain spirit sufficient for about two weeks.

Several of these beacons have been erected by the Swedish

lighthouse authorities, and are reported to be working satisfactorily. The light, although feeble as compared with Broadness, has worked regularly and without trouble or intermission since its installation in December 1885.

The total cost of the structure, including the illuminating apparatus, was £711 12*s.* 9*d.*, and the annual working expenses for the year ending December, 1886, were as follow:—

| | £. | s. | d. |
|---|---|---|---|
| Wages | 26 | 0 | 0 |
| Stores and incidental expenses | 9 | 17 | 5 |
| 200 gallons of petroleum spirit, including delivery | 19 | 10 | 0 |
| Repairs and renewals on building, 5 per cent. on £644 19*s.* 9*d.* | 32 | 4 | 11 |
| Interest on apparatus, 7½ per cent. on £66 13*s.* | 4 | 19 | 11 |
| | 92 | 12 | 3 |
| Interest on first cost 3½ " £711 12*s.* 9*d.* | 24 | 18 | 1 |
| | £117 | 10 | 4 |

## Broadness Lighthouse.

The light is produced by the combustion of compressed oil-gas, which is stored in two steel gasholders (Plate 6, Fig. 5), having a collective capacity of 280 cubic feet, arranged in the base of the structure. The gas is conveyed to the burner in the lantern by pipes, and is passed through two regulators for reducing and regulating the pressure at the burner. The fittings, which are in duplicate throughout, are so arranged that either holder or both can be used for the light. The gasholders are usually charged to a pressure of 5 atmospheres. When thus charged they contain 1,400 cubic feet of gas at atmospheric pressure. The consumption of gas is about 2·2 cubic feet per hour, at which rate the light will continue to burn for about six hundred and thirty-six hours. The illuminating apparatus (Plate 6, Fig. 6), consists of a two-ring Trinity House Douglass gas-burner, of 50-candle intensity, placed in the focus, and a fourth-order fixed dioptric lens of 250 millimetres (9·843 inches) radius, composed of a central belt and six refractors, with five prisms above and three below, embracing a vertical angle of 156°.

The character of the light is white, flashing at periods of ten seconds, giving a flash of three and one-third seconds, followed by an eclipse of six and two-thirds seconds. The flashes have an intensity of about 500 candles. The flashes and eclipses are produced by a specially designed piece of clock-work, which not only produces, by cutting off the gas, but regulates the flashes and eclipses; it also turns the gas on at sunset, and off at sun-

rise. The clock-work is further provided with an adjustment to meet the lengthening and shortening of the nights. This ingenious piece of mechanism was designed by Mr. G. H. Slight, the Superintendent of the Trinity Workshops, Blackwall.

The method of charging the gasholders at Broadness is similar to that already described for gas-buoys.

The total cost of Broadness, including the illuminating apparatus, was £945 12*s.* 3*d.*; and the annual working expenses are:—

| | £. | s. | d. |
|---|---|---|---|
| Wages . . . . . . . . . . . . . . . . | 26 | 0 | 0 |
| 10,000 cubic feet of oil-gas at 10*s.* per 1,000 cubic feet | 5 | 0 | 0 |
| Cost of delivery of gas by lighters (at present) . . | 25 | 0 | 0 |
| Stores and sundries . . . . . . . . . . . . | 13 | 14 | 3 |
| Repairs and renewals on building, 5 per cent. on £644 19*s.* 9*d.* . . . . . . . . . . . . | 32 | 4 | 11 |
| Interest on apparatus, gasholders, burners and fittings, 7½ per cent. on £300 12*s.* 6*d.* . . . . | 22 | 10 | 11 |
| | £124 | 10 | 1 |
| Interest on first cost 3½ per cent. on £945 12*s.* 3*d.* . | 33 | 1 | 11 |
| | £157 | 12 | 0 |

This apparatus has also worked with great regularity since its installation in December, 1885, and requires but little attention beyond the keeping up of the supply of gas, cleaning, oiling, &c.

Both Broadness and Stoneness lighthouses are under the charge of a boatman, who visits them at least twice a week, when he adjusts and cleans the apparatus and lantern glazing. The intensity of Stoneness light is, as already stated, 60 candles, and that of Broadness 500 candles, or as 100 to 833, while the annual cost of Stoneness is £117 10*s.* 4*d.* and that of Broadness £157 12*s.*, or as 100 to 134. In other words, taking both intensity and annual cost into consideration, Broadness Light has an efficiency of about 700 per cent. over that of Stoneness.

## Ailsa Craig Lighthouse.

An important installation of an oil-gas apparatus has recently been made by the Commissioners of Northern Lights at Ailsa Craig on the Frith of Clyde. This establishment consists of a lighthouse, on the eastern side of the island, dwellings for keepers, engine-house, retort-house, two gasholders having a collective capacity of 21,148 cubic feet, and a mineral-oil store, and workshops.

There are also two fog-signal houses, one at the north end of the island, 1,043 yards from the lighthouse, and the other at the

south end, 733 yards from the same. These are situated at the base of the rock.

Each fog-signal apparatus consists of an air-receiver; an automatic siren and trumpet, sounded by air compressed to 75 lbs. pressure per square inch, which is conveyed from the engine-house to each station by pipes laid in concrete underground.

The motive power is supplied by five "Otto" silent gas-engines of 8 HP. each. Four of these are employed for compressing air for the fog-signals, the fifth being kept in reserve in case of accident to any one of the others. The gas, being too rich for use alone by the engines, is mixed in one of Keith's mixers in the proportions of 65 parts of gas to 35 parts of atmospheric air. The consumption of gas by the four engines is 540 cubic feet per hour, or 830 cubic feet of air and gas mixed, being about 26 cubic feet of the latter mixture per HP. per hour; and the cost is 1·16*d.* per HP., omitting wages, depreciation, and interest on capital. The south signal gives high, low, and high notes in quick succession every three minutes, and the north signal a single note of five seconds' duration every three minutes, sounding at an interval of ninety seconds after the south signal has ceased. The fog-signal apparatus was supplied by the Siren Fog-signal Company (Limited). The gas-works and apparatus were supplied by Mr. James Keith of Arbroath, and are stated to be capable of producing 10,000 cubic feet of 60-candle gas in four and a half hours, or 2,222 cubic feet per hour, being at the rate of about 186 cubic feet per retort per hour. The relative quantity of gas produced from the oil is about 10,000 cubic feet per 100 gallons of ordinary illuminating paraffin, or 100 cubic feet per gallon (which is probably a maximum), with a consumption of about 20 to 30 cwt. of coal for heating the retorts and making the gas. The cost of the oil is $4\frac{1}{2}$*d.* per gallon, exclusive of delivery, and that of the coal, including delivery at Ailsa Craig, 9·6*d.* per cwt. The cost of the gas is therefore about 5*s.* 9*d.* per 1,000 cubic feet exclusive of labour, carriage of the oil, interest on capital, and depreciation of plant.

The illuminating apparatus consists of a dioptric lens of the third order, supplied by Messrs. Barbier and Fenestre of Paris, from the designs of Messrs. D. and T. Stevenson, of 500 millimetres (19·685 inches) radius. It is composed of 180° of condensing apparatus, constructed in six segments of 30° each, each segment condensing the whole light embraced within that angle into one of 10°. The refracting portion, subtending an angle of 65° vertically, is a differential refractor. The upper and lower prisms are of the form

suggested by Mr. Alan Brebner, jun., Assoc. M. Inst. C.E., for condensing by single agency.[1] The remaining 180° is made up by a dioptric mirror of 432 millimetres (17·008 inches) internal radius. The whole is rotated by clock-work, making 1 revolution in thirty seconds, producing six flashes in quick succession; the flashes occupying fifteen seconds, which are repeated after an interval of fifteen seconds. The illuminant is the flame of a two-ring Sugg gas-burner of 100-candle-units' intensity. The intensity of the flashes is estimated at 24,000 candles. The gas supplied to the burner is similar to that consumed by the gas-engines, being a mixture of oil-gas and air. The consumption is 15 cubic feet per hour at a water-pressure of 1·1 inch.

The cost of this installation was about £24,000, and the annual working expenses are about £725. For the above information the Author is indebted to the Paper by Mr. David Alan Stevenson, M. Inst. C.E.,[2] which Paper deals exhaustively with this important establishment.

The following is a statement of the number of gas-buoys, light-ships, beacons, and other lights in use in the undermentioned countries, on Pintsch's system, on December 1st, 1887:—

| Name of Country. | Buoys. | Lightships. | Beacons and other Lights. | Total. |
|---|---|---|---|---|
| Great Britain | 30 | 4 | 8 | 42 |
| Canada | 8 | .. | .. | 8 |
| Australia | 2 | .. | 1 | 3 |
| Holland and Colonies | 11 | 2 | 2 | 15 |
| Sweden | 1 | 1 | .. | 2 |
| Denmark | 5 | .. | 2 | 7 |
| France | 7 | .. | 1 | 8 |
| Germany | 5 | .. | 2 | 7 |
| Spain | 2 | .. | .. | 2 |
| Austria | 1 | .. | .. | 1 |
| Italy | 3 | .. | 2 | 5 |
| Russia | 4 | .. | .. | 4 |
| United States | 9 | .. | 1 | 10 |
| Brazil | 1 | .. | .. | 1 |
| Egypt (Suez Canal) | 59 | .. | 39 | 98 |
| Argentine Confederation | 1 | .. | .. | 1 |
| Total | 149 | 7 | 58 | 214 |

[1] Minutes of Proceedings Inst. C.E., vol. lxxvi. p. 386. [2] *Ib.* vol. lxxxix. p. 297.

## The Illumination of Railway-Carriages by Compressed Oil-Gas.

The application of compressed oil-gas to the lighting of railway-carriages is one of growing importance. It was probably first tried in the year 1871, with satisfactory results in Germany on the Lower Silesian Railway, and in England in 1876, on the St. John's Wood trains of the Metropolitan Railway, with equally satisfactory results. The Great Eastern Railway Company was the next to adopt it; the Metropolitan Railway Company definitely adopted it for the whole of its rolling-stock a few weeks later, other Companies quickly following suit. The systems chosen are those of Pintsch, and of Pope and Son, which differ but little from each other. Some trials were also made of Bower's system on the Great Northern Railway.

The gasholders are attached either to the roofs or to the under-framing of the carriages, and are charged to a pressure of from 6 to 8 atmospheres.

The gas is conveyed to the roof-lamps by pipes from the gas-holders, passing through a regulator similar to those previously described for adjusting the pressure at the burners, one such regulator being attached to each carriage.

Taking one of the London and North-Western Railway Company's 6-wheeled first-class carriages as an example, such a carriage carries two gasholders, placed side by side longitudinally, having a collective capacity of 27½ cubic feet.

The gas is conveyed, as above described, to the roof-lamps, seven in number, one to each compartment. The consumption of gas is to be restricted to 0·4 cubic foot per burner per hour, giving a gross consumption of 2·8 cubic feet per carriage per hour. A carriage thus fitted will run from Euston to Aberdeen and back, a distance of 1,080 miles, the lamps burning continuously for thirty-three hours, with only one charge of gas, the gasholders being charged to a pressure of about 120 lbs. per square inch, more or less. On arriving back at Euston there is usually about 20 lbs. pressure remaining in the holders, depending upon the pressure to which they were originally charged, also loss due to leakage, &c. The number of carriages so fitted to date are some fourteen hundred and sixty-two. The cost of the gas, delivered into the gasholders, is about 8*s.* 5*d.* per 1,000 cubic feet (after deducting the value of the residual products), which includes interest on capital and depreciation of plant.

For the double journey between Euston and Aberdeen, the cost of compressed oil-gas is 0·0404*d.* per lamp per hour, taking the value of the gas at 8*s.* 5*d.* per 1,000 cubic feet, and for the ordinary oil system, 0·385*d.* per lamp per hour, showing an increased cost of the ordinary oil system of eight and a half times that of oil-gas.

The system adopted by the London and North-Western Railway Company is that of Messrs. Pope and Son. The apparatus for making the gas, as described by that firm, consists of a set of cast-iron cylindrical retorts, 6 inches in diameter, arranged in pairs, placed one above the other, with drip-pipes for conveying the oil into the retorts, a hydraulic main, condenser, scrubber, and tar-wells, &c.

The oil is admitted in fine streams into the lower retorts, is converted into gas, and thence passes direct into the upper retorts, where the process of distillation is completed. From the upper retort the gas passes into the hydraulic main, under which is placed a safety seal and tar overflow; from this it issues into the condenser, to which is fitted a second safety seal-pipe and can. From the condenser the gas passes into the scrubber, at the bottom of which is fitted a third safety seal-pipe. The overflow of tar is carried into a tank underground, and pumped out as often as necessary. The gas now passes through the main into the gasholder, from which it is drawn by the compressing pump, and delivered into the distributing main.

This system differs from that of Pintsch's in that the oil, instead of being delivered on to sheet-iron trays in the upper retort, is delivered in a fine spray on to the floor of the lower retort. The passing of the gas through a mixture of sawdust and lime, as in Pintsch's system, is dispensed with.

In the Appendix a Table is given containing statistics relating to the manufacture and application of compressed oil-gas, by ten of the principal British Railway Companies, kindly furnished by the Locomotive and Carriage Superintendents of those companies.

From other information kindly furnished by Mr. Rickman, Managing Director to Pintsch's Patent Lighting Company, Limited, and by Messrs. Pope and Son, it appears that the number of railway-carriages fitted or being fitted in Great Britain and other countries is as follows :—

| | On Pintsch's system. | On Pope's system. |
|---|---|---|
| England | 4,400 | 4,389 |
| Germany | 14,898 | |
| France | 1,541 | |
| Austria | 454 | |
| Holland | 512 | |
| Russia | 601 | |
| U. S. America | 358 | |
| Switzerland | 210 | |
| Sweden | 144 | |
| Italy | 336 | |
| Denmark | 45 | |
| Total | 23,499 | |

Making a total of eight thousand seven hundred and eighty-nine, on both systems, for Great Britain; and for other countries, on Pintsch's system, of nineteen thousand and ninety-nine. Besides the above, nine hundred and four locomotive engines have been fitted or are being fitted upon Pintsch's system.

The advantages of compressed oil-gas, as an illuminant for gas-buoys, beacons, and railway-carriages, on account of its cheapness and portability, as compared with other sources of illumination, are great, and this system, until successfully rivalled by electricity or some other agency, must continue to be largely employed. Taking these important considerations into account, there appears to be no reason why it should not be more extensively adopted, and better lights maintained, although it must be admitted that, upon the whole, the lighting of railway-carriages has much improved of late.

The systems of Pintsch, Pope, and Keith differ but little from one another; the yield per gallon of oil, and cost of production, are much the same, and each system is equally dependent for its efficiency at the burner upon the employment of a perfectly constructed and suitable regulator.

### Lighting Mail-Steamers.

After a preliminary trial in 1880, the Dublin Steam Packet Company adopted compressed oil-gas for the mail rooms on board the steamers "Ulster," "Munster," "Connaught," and "Leinster," and also the new vessel "Ireland." Gas-works were erected at Holyhead, similar to those at Blackwall, the gas being compressed in gasholders to 10 atmospheres. From these the gas is conveyed through a $\frac{3}{4}$-inch lead pipe to a filling-box on the pier head, a

distance of about $\frac{1}{2}$ mile, and thence by a flexible hose to receivers on the main deck. The gas is reduced in pressure by a regulator, and is conveyed to the burners, at the ordinary pressure, through copper pipes. There are about thirty burners to each vessel. The cabins are, however, lighted by electricity.

The Author desires to record his great obligations to Mr. Rickman, Messrs. Pope and Son, and the Locomotive and Carriage Superintendents of the different railway companies, for the kind assistance they have rendered him.

The Paper is accompanied by several diagrams, from which Plates 5 and 6 have been engraved.

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[APPENDIX.

APPENDIX.—TABLE SHOWING the ANNUAL PRODUCTION and COST, &c., of COMPRESSED OIL-GAS as USED by the UNDERMENTIONED RAILWAY COMPANIES. CORRECTED to date.

| Name of Company. | System Adopted. | Cost of Works. | Number of Works. | Number of Retorts. | Yield per Retort per hour. | Number of cubic feet of Gas per Gallon of Oil. | Annual Production. | Value of Residuals. | Cost per 1,000 cubic feet, deducting Residuals, exclusive of Interest and repairs. | Cost per 1,000 cubic feet, deducting Residuals and adding Interest and Depreciation at 10 per cent. | Number of carriages fitted. | Consumption of Gas per burner per hour. | Intensity of flame in Standard Candles. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | £ | | | | | | s. d. | s. d. | s. d. | | | |
| London[1] and North-Western | Pope | 1,025 | Not stated | Not stated | Not stated | 77·00 | 6,160,000 | 0 6·90 | 6 10·30 | 8 9·60 | 1,462 | 0·4 | Not stated |
| Caledonian[2] . | Pintsch | 4,004 | 1 | 4 pairs = 8 | 480 to 600 | 81·17 | 1,891,700 | 1 1·24 | 6 7·24 | 10 10·26 | 603 | 0·74 | 8·25 |
| Great Western[3] | Pope | 3,000 | 1 | 8 „ = 16 | 170 to 200 | 75·80 | 2,800,000 | 0 9·60 | 6 3·1 | 8 4·81 | 146 | 0·75 to 1 | 6¾ to 9 |
| Metropolitan . | Pintsch | 8,000 | 2 | 8 „ = 16 | 150 to 175 | 77·00 | 8,500,000 | 1 10·0 | 6 0·00 | 7 10·59 | 310 | 1·035 | Not stated |
| Midland . . | Do. | 4,149 | 1 | 3 „ = 6 | Not stated | 74·16 | 3,948,000 | 0 3·75 | 7 0·5 | 9 1·72 | 182 | 0·75 | 6 |
| Glasgow and South-Western | Do. | 3,500 | Not stated | 2½ „ = 5 | „ | 76·25 | 1,315,680 | 0 9·00 | 6 6·71 | 7 1·09 | 440 | Not stated | Not stated |
| London[4] and South-Western | Do. | 6,237 | 2 | 10 „ = 20 | 507·0 | 81·00 | 2,696,760 | 0 9·00 | 5 8·25 | 11 9·28 | 890 | 0·70 | Do. |
| Great Eastern . | Do. | 6,900 | 1 | 6 „ = 12 | 134·5 | 72·00 | 3,460,000 | 0 8·25 | 6 2·5 | 10 2·36 | 611 | 0·75 | 7·4 |

NOTE.—The cost per 1,000 cubic feet is calculated on the total quantity of gas produced per annum, reckoning, for the sake of comparison, interest on capital and depreciation of plant at 10 per cent. The quantity of gas available for lighting is probably 10 per cent. less (due to loss by condensation and leakage) than the total production.

[1] Cost of works at Euston. The cost of the gas per 1,000 cubic feet is deduced from a thirty-two days' continuous trial at those works, during which 252,700 cubic feet of gas were produced. [2] and [4] The large yield per retort per hour in these cases is not explained, but is probably due to the dimensions of the retorts and the rate at which the oil is admitted into them. [3] Works of galvanized iron.

[DISCUSSION.

## Discussion.

Sir James N. Douglass.

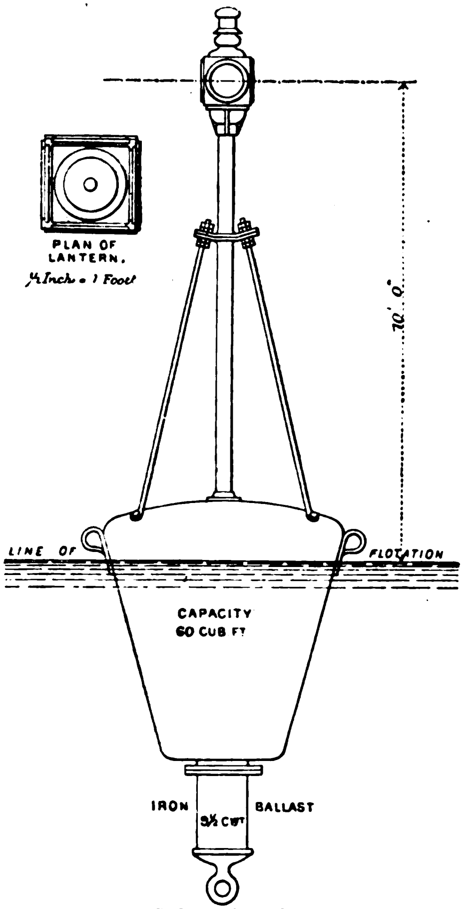
Sir JAMES N. DOUGLASS wished to refer to the experiments made with the first gas-lighted buoy submitted, by Messrs. Pintsch, to the Corporation of Trinity House in 1878. It would be seen, from Fig. 1, that it was not of a suitable form for perpendicular riding, and had an imperfect square lantern, but the buoy was sufficient to satisfy the Corporation that the invention was a most valuable one for auxiliary coast lighting, and further experiments were undertaken, for which special buoys were constructed. For these experiments the spherical form, and the hollow bottom of Herbert [1] were adopted, the latter for securing perpendicular riding, and thus the uniform distribution of the beam from the lens over the surface of the sea. The buoy was also provided with a cylindrical lantern; and for the light a lens was specially designed by Dr. Hopkinson, M. Inst. C.E., a specimen of which he exhibited. In addition to the ordinary lens, which subtended a vertical angle of 58°, or 60°, Dr. Hopkinson, by the introduction of an extra ring of dense flint glass, at top and bottom, increased the vertical angle subtended to 90°, thus considerably augmenting the efficiency of the lens. The lens was the smallest ever constructed for coast-light purposes, and was a beautiful piece of optical work. Two compartments were adopted in the experimental buoys, so that in case of collision, and the outer compartment becoming filled with water, the inner one would supply gas, and keep the light going. Extinction of the light, however, occurred occasionally, and that, perhaps, was the only imperfection connected with the buoys. A baulk of timber, or a boat, heavily striking them would cause oscillations of the membrane of the regulator and extinguish the light. This difficulty had yet to be surmounted. It was very remarkable that heavy guns fired at a distance of 2 or 2½ miles would occasionally extinguish the light. The buoy exhibited by the Author was a further development of these buoys, and the Herbert principle of bottom. As explained in the Paper, these buoys were so arranged that the shape of the upper part might be changed, becoming either spherical, conical, or can-formed, to meet the requirements of the new uniform system of buoyage. It was apparent that there would be no difficulty in increasing the dimensions of such structures for lighting purposes at sea; but, at present, progress was slow in that direction. The buoys illustrated weighed about 6 tons, which was a fair weight for handling at

[1] Minutes of Proceedings Inst. C.E., vol. xv. p. 1.

Sir James N. Douglass.

sea by the steam-craft usually employed for lighthouse purposes, and the dimensions were found to be sufficient where the buoys were employed as auxiliary lights. But for the more important lights the system was considered to be still wanting in that trustworthiness which should be the leading characteristic of all coast-

Fig. 1.




Scale ¼ inch = 1 foot.

lights. For auxiliary or port lights on shore, where no collision could occur, the system was excellent. At Broadness-on-the-Thames, the light had proved very efficient. With the special clock-work referred to by the Author, it had fulfilled all the requirements of a perfect lighthouse of the moderate intensity of

Sir James N. Douglass.

500 candles. It was evident, however, that the system would not compete with mineral oil in point of cost for a first-class coast-light of the high intensity now demanded. The Lindberg and Lyth system at Stoneness had worked very satisfactorily. Where few lights were required by the responsible authority, and where the expense of the installation of the gas apparatus was not justified, and a focal intensity was not demanded exceeding 60 or 80 candles, it was an admirable appliance for the purpose. It was, however, to be remembered that the illuminant dealt with was very dangerous; for the petroleum spirit, required for this light, flashed at ordinary temperatures of the atmosphere, and had to be very carefully handled in transport, in storage, and in the lantern. Very complete arrangements were made for good ventilation in the Stoneness lantern. There would evidently be great risk in adopting higher intensities without corresponding increase in the dimensions of the lantern. As to the comparative cost of compressed oil-gas and petroleum spirit, it was impossible at present to speak confidently. From the figures given by the Author it appeared that the cost of installation was about 30 per cent. higher for gas than for petroleum spirit; but it should be remembered that the petroleum-spirit apparatus was only of 60-candle power, while that of the gas was 500, or eight and one-third times the intensity. The cost of petroleum spirit per unit of light in the flash per annum was 39*s.*, while that of gas was only 6*s.* 3*d.* Considering the handiness of the compressed oil-gas apparatus, and the readiness with which it lent itself to all the optical requirements, there could be no doubt that it was the most complete agent known at the present time. The only rival that could be expected to appear was electricity, with which unfortunately little had, as yet, been practically done. He desired, however, to record a successful experiment made in lighting a beacon by electricity on a tidal rock in the Bay of Cadiz, in 1884, by Mr. Isas Lavoden, of Cadiz. The apparatus consisted of a 6th Order Fresnel lens for fixed light with a glow lamp of 3-candle intensity at the focus, thus giving an intensity in the issuing beam of about 20 candles. The electric current was supplied from a secondary battery placed in a closet under the lantern. The light was arranged to show a flash of five seconds' duration, followed by an eclipse of twenty-five seconds. The making and breaking contact for the flashes and eclipses was accomplished by a small spring clock arranged to run for twenty-eight days, and which also eclipsed the light between sunrise and sunset. He

had seen this light after it had been working four months, and was informed by the inventor that no accident had occurred to it during that time. Sir James N. Douglass.

Mr. JOSEPH TOMLINSON, jun., said that having been one of the Committee appointed by the Society of Arts, together with Sir Frederick Abel and Mr. Myles Fenton, to adjudicate as to the "best system for lighting railway trains," and which society, on their report, awarded the gold medal to Julius Pintsch of Berlin, it was only fitting that he should say a few words on the Paper, as he considered himself responsible for the introduction into this country of the system known as Pintsch's, which was now so largely adopted. He would first, however, correct one or two inaccuracies in the Paper. On p. 302 it was stated that the oil cistern was "placed on the top of the retort bench." This plan he had not adopted, and did not consider safe, as any one who had worked it for a short time would know that, if any slight stoppage took place, the pressure would rise and break the seal by blowing out the oil, and would set fire to the vessel of oil; and if of sufficient duration the flame might destroy the can or cistern, and a fire would result. He had therefore put the vessel of oil a considerable distance away on the side of the wall, leading only a pipe to the bench. The illuminant intensity of the gas, which he had been able to make for the railway for many years, was 51 candles before compression, and 38 after compression to 150 lbs. per square inch. The quantity of hydrocarbon given in the Paper was as nearly correct as possible, namely, 1 gallon per 1,000 cubic feet when compressed to 10 atmospheres. But he had never got regularly 90 cubic feet of good gas. He had had as much as 100 cubic feet, but could not maintain it hour by hour. The average for many years had been from 80 to 83 cubic feet, with the best oil that could be obtained, and he did not agree with the Author that the quantity of the oil was unimportant. The proposed completion of the Inner Circle of the Metropolitan and District Railway between Aldgate and Mansion House, which would cause continuous running for the whole of twenty hours, made some change necessary, as the trains could not have been worked on the old plan. At this time the Pintsch system, which was in use in Germany, having been brought before his notice, he examined the system at Berlin. It seemed so complete and good that at first he hardly credited it, and went a second time to satisfy himself of its excellence. After careful deliberation it was decided to adopt the Pintsch plan on the Metropolitan Railway, and the trains began to run with the new light in 1876, and it had been Mr. Tomlinson.

METROPOLITAN

COMPARATIVE STATEMENT showing

| — | Ordinary Coal-Gas. | | | | | |
|---|---|---|---|---|---|---|
| | Half Year ending June 1873. | Half Year ending Dec. 1873. | Half Year ending June 1874. | Half Year ending Dec. 1874. | Half Year ending June 1875. | Half Year ending Dec. 1875. |
| | Train-Miles 435,419 | Train-Miles 435,760 | Train-Miles 446,949 | Train-Miles 437,897 | Train-Miles 440,263 | Train-Miles 449,758 |
| | £. s. d. | £. s. d. | £. s. d. | £. s. d. | £. s. d. | £. s. d. |
| *Traffic Charges*— | | | | | | |
| Gas . . . . | 1,801 1 7 | 1,789 18 6 | 2,187 3 1 | 2,159 2 5 | 1,910 0 0 | 1,896 19 1 |
| Oil (for Silber lamps) . . . | 66 8 2 | 80 18 2 | 83 7 2 | 54 2 5 | 31 0 0 | 59 0 0 |
| Cotton (for Silber lamps) . . . | 2 1 9 | .. | 1 7 6 | 0 12 0 | .. | |
| Making Pintsch gas— | | | | | | |
| Wages . . . | .. | .. | .. | .. | .. | .. |
| Materials . . | .. | .. | .. | .. | .. | .. |
| Gasmen's wages . | 343 16 2 | 327 7 10 | 289 3 0 | 314 2 11 | 393 17 2 | 450 9 2 |
| Repairs of gas-apparatus . . | 10 8 1 | 20 15 7 | 27 9 2 | 34 13 10 | 96 1 3 | 98 1 11 |
| Repairs of lighting up lamps . . | 0 4 3 | .. | 0 5 9 | 0 6 6 | 0 1 3 | |
| | 2,224 0 0 | 2,219 0 1 | 2,588 15 8 | 2,563 0 1 | 2,430 19 8 | 2,504 10 2 |
| Per train-mile . | 1·23*d.* | 1·22*d.* | 1·39*d.* | 1·40*d.* | 1·32*d.* | 1·34*d.* |
| *Charges borne by Carriage Department*— | | | | | | |
| Repairs of gas-bags and fittings | 352 15 1 | 212 10 6 | 220 17 3 | 333 15 3 | 242 13 8 | 275 3 3 |
| Repairs of gas-containers and fittings . . . | .. | .. | .. | .. | .. | .. |
| Repairs of gas-lamps . . . | 107 8 9 | 145 16 3 | 132 0 0 | 101 16 1 | 103 15 2 | 92 0 8 |
| Repairs of oil-lamps . . . | 17 11 0 | 9 4 1 | 12 9 5 | 10 1 0 | 9 11 3 | 8 18 5 |
| Maintenance of gasometers . . | 11 16 5 | 18 18 10 | 0 5 3 | 2 3 9 | 2 2 2 | |
| Maintenance of gas-works . . | .. | .. | .. | .. | .. | .. |
| | 489 11 3 | 386 9 8 | 365 11 11 | 447 16 1 | 358 2 3 | 376 2 4 |
| Per train-mile . | 0·27*d.* | 0·22*d.* | 0·20*d.* | 0·25*d.* | 0·20*d.* | 0·20*d.* |
| Total . . . . | 2,713 11 3 | 2,605 9 9 | 2,954 7 7 | 3,010 16 2 | 2,789 1 11 | 2,880 12 6 |
| Total per train-mile | 1·50*d.* | 1·44*d.* | 1·59*d.* | 1·65*d.* | 1·52*d.* | 1·54*d.* |

RAILWAY.

COST of LIGHTING CARRIAGES.

| Pintsch's Oil-Gas. | | | | | |
|---|---|---|---|---|---|
| Half Year ending June 1882. | Half Year ending Dec. 1882. | Half Year ending June 1883. | Half Year ending Dec. 1883. | Half Year ending June 1884. | Half Year ending Dec. 1884. |
| Train-Miles 742,023 | Train-Miles 768,689 | Train-Miles 766,281 | Train-Miles 789,186 | Train-Miles 782,353 | Train-Miles 885,565 |
| £. s. d. | £. s. d. | £. s. d. | £. s. d. | £. s. d. | £. s. d. |
| 3 1 4 | | | | | |
| 411 8 0 | 408 11 0 | 357 5 3 | 383 6 5 | 401 9 0 | 390 3 9 |
| 1,508 9 7 | 1,301 14 6 | 1,199 17 2 | 1,140 14 0 | 1,144 2 11 | 1,404 2 9 |
| 348 5 11 | 340 5 2 | 394 7 0 | 422 1 0 | 403 3 8 | 426 2 6 |
| 70 17 6 | 42 9 8 | 47 18 0 | 90 12 4 | 172 10 9 | 320 15 2 |
| 2,342 2 4 | 2,093 0 4 | 1,999 7 5 | 2,036 13 9 | 2,121 6 4 | 2,541 4 2 |
| 0·76*d.* | 0·65*d.* | 0·63*d.* | 0·62*d.* | 0·65*d.* | 0·69*d.* |
| *Cr.* *310 15 3* | .. | .. | .. | *Cr.* *32 8 3* | |
| 138 7 3 | 120 12 0 | 147 5 10 | 129 18 11 | 109 14 6 | 129 7 11 |
| 67 11 3 | *Cr.* *1 2 0* | 63 13 3 | 76 16 10 | 65 19 11 | 45 2 11 |
| 622 14 5 | 567 18 11 | 446 14 3 | 478 10 7 | 585 3 7 | 640 0 5 |
| 517 17 8 | 687 8 11 | 657 13 4 | 685 6 4 | 728 9 9 | 814 11 3 |
| 0·17*d.* | 0·22*d.* | 0·20*d.* | 0·21*d.* | 0·22*d.* | 0·22*d.* |
| 2,860 0 0 | 2,780 9 3 | 2,657 0 9 | 2,722 0 1 | 2,849 16 1 | 3,355 15 5 |
| 0·93*d.* | 0·87*d.* | 0·83*d.* | 0·83*d.* | 0·87*d.* | 0·91*d.* |

Mr. Tomlinson. in use ever since without a hitch of any kind. From 1876 to 1881 was a transition period, changing the fittings on the carriages, and during that time both the old gas plan and the Pintsch system were in operation, and not till 1881 were all the carriages refitted. Having perfect confidence in it, and as the Directors of the Company would not give any capital money, he offered to make the change at the cost of revenue, if they would give a suspense account while the change was taking place. This having been agreed to, he had paid off the whole cost of conversion in about three years out of savings, the whole amount being about £9,000. The only charge that went to capital was the actual gas-works, buildings, and fittings, and travelling plant, the latter consisting of trucks and boilers. This outlay, as regarded rolling-plant, was required in consequence of the number of places at which trains had to be put away at night, and to allow of all gas-making at one place; also to enable the trains to be fitted at night. The Author stated that the consumption of gas on the London and North-Western Railway was 0·4 cubic foot per burner per hour, but he thought that was an error. On the Metropolitan Railway the consumption was 0·7 cubic foot taking the whole time. The cost of compressed oil-gas was given as 0·0404*d.* per lamp per hour, which was clearly wrong; in fact the whole of this paragraph was incoherent. He could not reconcile the figures in the Appendix with his own figures. On the Metropolitan, 1,000 cubic feet of gas gave 1 gallon of hydrocarbon, which he sold eventually for 2*s.* At first he could only get 2*d.* for it, but the Belgians competed for it, and at length gave 2*s.* The list of carriages was also wrong. The Lancashire and Yorkshire Company had a large number fitted. The Metropolitan District Company alone had three hundred, and the South-Eastern a great many. The Mersey Railway was not included in the list. With regard to the cost on the Metropolitan Railway from the time of his joining it in 1872, during the first three perfect years with ordinary coal-gas, the cost worked out at 1½*d.* per train-mile, with trains consisting of fifty lights. The light itself, with the attendance, came out at 1¼*d.* for the first three years; and the reparation of the gas-bags, fittings and lamps, amounted to a little over ¼*d.* Taking the last three perfect years, when the two systems were not in operation, the cost worked down to from 0·95*d.* to 0·83*d.*, or not much more than one-half. They had run under 900,000 miles in each year for the first three years, and over 1,500,000 each year in the last three years, and the total amount of money expended was given on the accom-

panying Table, which showed, comparing the three whole years before beginning the Pintsch system, and the three perfect years afterwards, that the cost per train-mile (fifty lights) with the Pintsch system was 0·209*d.* per light per hour, while the cost of coal-gas with the old system was 0·369*d.* Adding capital and interest, the cost came to 0·263*d.* for the Pintsch system, and 0·396*d.* for coal-gas. The cost of an oil-lamp made up by the London and North-Western Railway, as given to him in 1876, was 0·44*d.* per hour; this from his experience should be 0·495*d.*, including interest, depreciation, &c.; whereas the Author mentioned only 0·385*d.* for an oil-lamp of the same Company. Sir James Douglass had said that the lights went out if the buoys on which they were fitted came into collision. He thought that might be avoided by a plan something like that which he had himself adopted, namely, of putting a small chamber of gas between the regulator and the burner. He was compelled to do this when turning down the small burners with a by-pass for reducing the lights when running in open spaces by day. Mr. Tomlinson.

Sir FREDERICK BRAMWELL thought it might interest the Institution to be reminded of the use of compressed oil-gas very many years ago. It was nearly sixty years since compressed oil-gas was commonly sold in London, and used in offices as a means of illumination, to replace candles and lamps. The mode in which it was compressed was worthy of being remembered, for this reason, that as long ago as he had mentioned, the compressing pump, being of the plunger description, and, therefore, one that would ordinarily have been said to be one of a bad description, to effect compression without leaving large clearance spaces occupied by the compressed gas at the turn of the stroke, was made into an efficient pump by the expedient of introducing into it mercury, which filled up the whole of the otherwise vacant spaces, and caused an absolute delivery. The bottles in which the gas had been sold, were, for many years after it went out of fashion, to be found in what was now the Vauxhall Bridge Road, on a piece of waste ground, and many an apprentice in his day was glad to get one of these bottles, for the purpose of making model boilers and things of that kind, for which they were very valuable. He might mention that he had seen gas made from oil at an hotel near the great Adelsberg cavern, on the road from Vienna to Trieste. The hotel was illuminated by oil-gas, not compressed, but the oil used was known as fusel-oil produced in the distillation of grain. He wished to ask the Author whether there was any difficulty from deposit in the retorts, also of what materials the retorts were made? Sir Frederick Bramwell.

Mr. Keith. Mr. JAMES KEITH said that on some of the points mentioned in the Paper a little more enlightenment and a few corrections appeared to be necessary. He had been actively engaged, during the past twenty years, in experimenting on the best mode of making a permanent and pure gas from mineral oils, and in applying it to lighting and power purposes, so as to render the system popular and satisfactory. As a pioneer, therefore, in the successful manufacture and application of mineral oil-gas in this country, and seeing that his name had been mentioned in the Paper, he might be permitted to supplement the information given by the Author. Instead of one patent, as stated, three patents had been granted to him in connection with the manufacture and application of mineral oil-gas during the past fourteen years, viz., one in 1874, another in 1881, and a third in 1887. In each case the apparatus for making the gas had been designed to obtain the following objects: the maximum yield of gas, with the minimum consumption of fuel for heating the retorts; a cool and permanent gas, capable of being used as it was being made, continuously, without leaving any deposit, and with the smallest possible attention in working. The results had been fairly successful, seeing that the original single-retort apparatus of 1874, with one fire, making at least 200 cubic feet of gas per hour, could be heated from the cold state in from one hour to one hour and a half; while the later four-retort producer of 1881, with one fire, making at least 1,000 cubic feet per hour, could be similarly heated up in at most from three to four hours. For instance, in an ordinary coal-gas apparatus at a private house in the country, where the retorts were of the common form, and were set in even the best way, the cost of fuel for heating the retorts, say once a week, or once a fortnight, was the principal item of expenditure in the gas-making; but, in a properly-constructed oil-gas apparatus, that heating-up item should be a mere bagatelle, the principal expense being for the oil used for carbonizing. It would thus be seen that he had put considerable emphasis on the construction of the apparatus, in order to get the best results. The quality of the oil, again, was an important point, and he had used a thickish blue oil that gave about 50 per cent. more cubic feet of gas to the gallon than ordinary paraffin-oil at a less price would give, the quality of the gas produced, and the retort heat, being practically the same in both instances. The Author had omitted to mention the oil-gas installation works at Langness Point, Isle of Man, erected nine years ago, for the Commissioners of Northern Lights, and which had an importance of its own, in being the first public place where the

practical solution of the question of running gas-engines successfully by rich oil-gas took place, much to the surprise of the makers of the engines, who had predicted failure from the first. The Langness installation was used exclusively for working fog-signals, and it was owing to its unqualified success that the larger undertaking on Ailsa Craig Rock, Firth of Clyde, was contemplated. The Author had properly described the Ailsa Craig installation as "important," seeing that it was the largest installation of its kind, as far as he knew, and that it eclipsed all similar undertakings where mineral oil-gas was used. The particulars were fairly stated by the Author, but he might add that a guarantee was given that 2,000 cubic feet of rich oil-gas should be made per hour, while on test, after the work had been finished for some time, 3,500 cubic feet were made per hour, that being practically equivalent to 300 cubic feet per hour per retort. There were three gas-producers, with four retorts and one fire in each producer; thus there were three fires and twelve retorts in all. There were six gas-engines, representing 42 nominal HP., in connection with the installation, for fog-signaling and for hauling purposes, and the gas-work furnished all the power requisite on the island, as well as all the light for the lighthouse, offices, &c. He did not agree with the Author that his system did not differ from those of other makers, and he would point out wherein the difference lay. He believed in rapid making, thorough washing, and rapid and thorough atmospheric cooling of the gas, to such an extent that his apparatus was unlike any other in its general principle and construction, and in the results obtained, on the points mentioned. Again, in using the gas, though the rich 50- or 60-candle gas was stored in the gas-holders, it was not supplied alone at the points of combustion or consumption; but the gas was passed through a meter-mixer after it left the gasholder, which automatically measured an admixture of air to the gas in certain proportions as the gas was being used, adding, as it were, to the volume of the gas in consumption, but in no way reducing the consumption of rich gas. That enabled the oil-gas to be employed for lighting, heating, or for power purposes, giving far better results in each case. It would be observed that by that arrangement the rich oil-gas was brought back, but in the consumption only, to the standard of any ordinary coal-gas that might be adopted, thus allowing the gas to be used with any burners or fittings suitable for ordinary coal-gas. He generally, in that way, brought the rich oil-gas back, in consumption, to good Scotch coal-gas standard, for ordinary purposes, and a large range Mr. Keith.

Mr. Keith. of burners, from No. 1 to No. 6, could then be used for lighting without vestige of smoke. He was informed by those who had substituted that arrangement for the former rich gas, that the flame was whiter and clearer, and the light better diffused. For the driving of gas-engines, again, by rich oil-gas, the air-mixing arrangement was indispensable where regularity and reliability in running were essential; while the gas itself, so treated, acquired considerably more dynamic force than coal-gas of the same standard had under explosion. The gas, both at Langness and on Ailsa Craig, was treated in that way, and the working of the power appliances at these installations was almost perfect. He must admit that he had not given special attention to the using of mineral oil-gas under compression, his efforts having been principally directed more to the economical manufacture of the gas in a permanent form, and its ordinary application to power and lighting purposes. As far, however, as the application of oil-gas to the illumination of country houses and other land stations was concerned, he thought compression was wholly unnecessary, since it only increased the cost of the illuminant, without giving any material benefit in return. Again, where compression was necessary at the gas-works, he scarcely saw what was gained by using steam-power, when the gas was available for driving the compressing gear so effectively, and at the moderate cost of about 1*d.* per HP. per hour, as exemplified even on an isolated rock like Ailsa Craig. In regard to the application of compressed oil-gas to buoys and beacons at sea, and to railway- and other carriages on land, there could be little difference of opinion, as its successful adaptation marked a distinct advance in the history of oil-gas. As an agent of light and guidance to the commercial navy, as a medium for increasing the comfort of those who dwelt in remote places, and as a factor in lessening the discomfort and danger of the travelling public, he thought mineral oil-gas was becoming increasingly of national importance.

Mr. Reinhold. Mr. C. Reinhold, as the Engineer of Pintsch's Patent Lighting Company, could not speak of the merits of that system; but he thought it might be interesting for the members to hear of its further progress. How successful it had been in lighting railway-carriages had been sufficiently proved by the number of carriages now running lighted by compressed oil-gas. Notwithstanding the trials which for years had taken place for the same purpose, very little progress had been shown with electric light, and he maintained that an oil-gas light was more reliable, much cheaper, and, as shown on some of the underground lines, at least

as good, if not better. In comparing the two lights, the question of cost should never be lost sight of, and he was sure oil-gas would be found much the cheaper. The post-office of the Irish mail-boats had been lighted by Pintsch gas for the last six years, and it had proved so satisfactory that, although the cabins and saloons of the vessels were lighted by electricity, the oil-gas had not only been retained, but the new boat "Ireland" had also been fitted with that system. The lighting of buoys, beacons, and lighthouses had been an equal success. Besides the places mentioned by the Author, gas-buoys had been used by the Clyde Lighthouses Trustees, who were the first to adopt them officially. The Trustees now had four buoys, three beacons, one light-ship, and also worked two fog-signals at the Toward Point and the Cumbrae on the same system. One of the buoys at Skelmorlie bank had been run into by a steamer and a rent of 4 feet made in the hull. The buoy kept afloat, and notwithstanding the shock and the heeling over to an angle of 45°, the lantern not only remained intact but alight. The Suez Canal Company was the next officially to adopt gas-buoys and beacons, with the result that the Canal was now as easily navigable by night as by day. The buoys employed by that Company were spherical, 9 feet in diameter, with an inner gas chamber of sufficient capacity to hold gas for two months' continuous burning. The lantern was supported on the buoys by a superstructure, and stood about 12 feet above the level of the sea. The Pintsch Company had at present an order on hand for thirty-six beacons for the Suez Canal Company. The Clyde Navigation had nine buoys, one light-ship, one beacon, two lighthouses, and three light-towers, which greatly assisted the navigation by night. Besides buoys and light-ships at Barrow-in-Furness, and on the Tees, the Mersey Dock and Harbour Board had had oil-gas-works built, and had lighted the Crosby and Queen's Channels by means of buoys, placing a steady light on one side and a flashing light on the other. The system had been an entire success, and although the somewhat delicate flashing apparatus previously described had been applied, it had never given any trouble since it was introduced in May 1887. The pattern of the Mersey buoys differed from those constructed by the Trinity House. The former buoys were simply adaptations of their conical and can buoys to the system by placing a gas-cylinder inside and a lantern on top of them. The Melbourne Port and Harbour authorities had adopted the Pintsch buoys and beacons, and had a gas-works erected, and his Company were about to construct similar works for the Irish Mr. Reinhold.

Mr. Reinhold. Light Commissioners for the Bull Rock Lighthouse. He might also mention that the Company had built twenty-seven gas-works in England, and he hoped that would be a sufficient proof of the success of the Pintsch system.

Mr. Preece. Mr. W. H. PREECE said both in the Paper, and in the discussion, some hopes and fears had been expressed that in the distant future electricity would be used for artificial illumination, to the detriment of coal-gas and oil-gas. He did not think that future was distant. Electricity, as a source of artificial illumination, was making progress with giant strides, and he thought the discussion would scarcely be complete without reference to what had been done, and to what was likely to be done, in its application to some of the purposes mentioned. It was extremely difficult to draw a comparison between the value of electricity, as a source of illumination, and gas, because the units with which the consumption was measured in the two cases were of different dimensions. The consumption of gas was measured by reference to volume, and the consumption of electricity by reference to energy; and although it was somewhat difficult to show how the two were related, a few figures would perhaps make it evident. Let it be assumed that 25 cubic feet of gas would give 1 HP. (some engines would yield this with less, while others took a great deal more gas); 1 HP. was equivalent to 746 watts. Many persons imagined that a watt was an electrical unit, but it was nothing of the sort; it was a mechanical unit, pure and simple. It was a unit of power, and it was about one-fourth less than a foot-lb. per second. It had been objected to, because it was a new unit, based upon the centimetre, the gramme, and the second, the HP. being based on the foot, the lb., and the second. But the watt was an extremely useful unit, and it would assuredly be adopted by the next generation of engineers; it would then be used far more frequently than "horse-power" was now. The unit about to be employed as a mode of charging for electricity supplied to houses was one thousand watt-hours, which was known as the Board-of-Trade unit. The charge was 7½*d.* per thousand watt-hours, equivalent to 1·34 HP., and this would be produced by 33·5 cubic feet of gas; 1,000 cubic feet of gas would give 40 HP., or 29,840 watts, in round numbers 30,000. That would supply a mode of comparison between the energy of electricity and the energy of gas. If light was produced from gas, for every 1,000 cubic feet of gas burned per hour there was a production of 3,000 candles; if it was produced by compressed oil-gas, there was a production of 9,000 candles; but taking the same power as was given out by

1,000 cubic feet of gas in the shape of electricity, there was a production, with the ordinary glow-lamp, of 14,920 candles, or, using an arc-lamp (one of the most brilliant forms of electric lighting), there was a production of 90,000 candles. That showed how wasteful it was to use gas as an illuminant when, if it were used as power applied to the production of currents of electricity, thirty times as much light could be obtained. Taking it another way, if it was desired to obtain 10,000 candles by the consumption of gas, it would cost 10*s.*; if by means of electricity, through the glow-lamp, it would cost 7*s.* 6*d.*, so that electric light could be produced at the present day more cheaply than gas. Those were not mere estimates, but figures resulting from practical measurements in the application of electricity. On the question of economy, it might be said that the utilization of electricity as an illuminant was assured. The Paper had shown how artificial illumination could be applied to many useful purposes. He did not say that electricity could yet be satisfactorily and economically applied to the lighting of buoys as the Author had described. Some of the buoys maintained a light of about 5-candle-power for one hundred and six days and nights. Electricity had not yet done that, but he believed it would do so. For the production of light such as that in the Broadness lighthouse, and other places where gas could be adopted as a source of power, he believed electricity would be most useful and economical. But the great field of electricity that remained to be developed was, in his opinion, the lighting of railway-carriages. A great deal had been done in that direction. The Pullman cars of the express train leaving Victoria Station for Brighton, at 10 o'clock in the morning, were lighted by storage batteries. The Great Northern Company had also applied electricity to a similar purpose, and the London and South-Western Company was doing something in the same direction. The London and South-Western Company was experimenting with a new primary battery, and he was now able, through the kindness of Mr. Schanschieff, to exhibit some of those batteries. He was in the habit, when travelling, of carrying his own electric lamp with him. He had not one with him then, but he had an adaptation of one which Mr. Schanschieff had prepared. He carried the battery in his dressing-bag, and fixed the lamp on the side of the seat, so that a newspaper or book could be read with the greatest comfort. His own lamp had a secondary battery, but the one he was exhibiting was a candle-lamp, which Mr. Schanschieff had adapted to electricity. He also exhibited another lamp for lighting railway-carriages, and it would Mr. Preece.

Mr. Preece. be seen that the light was considerably brighter than from any other kind in common use. The battery would carry its charge for about twelve hours. There was yet another mode shown of applying electricity to an ordinary lamp, and that was certainly a purpose to which electricity would be extremely appropriate in hot countries. There was an ordinary carriage-lamp, with a battery inside; the plates were lowered into the solution, and the light would remain active for ten or twelve hours. Judging from actual experience, not only in his own house, but also at the Post-office and other places, he believed that electricity, both for simplicity and efficiency, would be found in the future a far more satisfactory source of producing light than coal-gas or compressed oil-gas.

Mr. Killingworth Hedges. Mr. KILLINGWORTH HEDGES said he had recently had an opportunity of comparing electric light in trains with gas-light over the same line, the Glasgow City and District. The oil-gas system had been adapted to several trains on that line, and a number of carriages had been fitted with the system of Mr. Carswell, the electrician of the North British Company, which had been working successfully for some time. By that system there was a central rail between the ordinary rails. There was a series of tunnels, alternating with open cuttings, and when the carriage arrived at the tunnel contact was made with the centre rail, and the light was produced. Compound dynamos were kept running at the Queen Street station, and no attention was required to be given to the lamps, which automatically lit and extinguished themselves. The cost of running the engine and dynamo, including repairs, was 0·33*d.* per lamp per hour, lamp renewals 0·07*d.*, total 0·4*d.* per lamp per hour. That was rather more than gas, but at the present time only one hundred and seventy carriages had been fitted. The plant was sufficient for five times that number, and if the engine was kept running continually the expense would be very little more, so that it would bring down the cost to less than that of gas. The cost of gas, as contracted to be paid to the Pintsch Company by the North British Railway Company, whose carriages were used, was 7*s.* 6*d.* per 1,000 cubic feet, and it came to 0·16*d.* per lamp per hour. He did not know where the trains quoted by the Author were running. He had made inquiries, but had not found any that were running lighted at the cheap rate mentioned in the Paper. The Author had stated that the gasholders might be carried under the frame of the carriages, but he thought that was dangerous, and should be condemned. Only last year a serious accident occurred on the Berlin and Potsdam Railway from that cause. A goods-train ran into a passenger-train, and perforated

the gas-cylinder carried under a second-class carriage; the gas was set on fire, and the passengers, before they could get out, were roasted. He was informed that the cost of applying electricity to the carriages built by the North British Railway Company was £15 per carriage, and the cost for gas was £30, showing a great saving on the first cost of electricity. Mr. Killingworth Hedges.

Mr. CHARLES INGREY thought the facts and figures, given in the Paper and in the discussion, would be of great benefit to those who were engaged in the development of hydrocarbon oil, an enterprise which had a vast future before it. The Paper treated of three distinct applications of hydrocarbon oil: first, the generation of gas from the heavy kinds of oil by means of gas-works, the mechanical compression of the gas so produced, and the storage in hermetically sealed vessels, whence it was conveyed to the point where it was to be used; secondly, the generation of gas from heavy oils by retorts, and the storage of that gas in gasholders, whence it was used on the spot for producing power, heat, or light, as the case might be; and thirdly, the Author had given an example of the application of the light form of oil or petroleum spirit, as at Broadness, where the oil was allowed to flow by gravitation to the burner, where it was consumed by the heating of the burner itself. He thought it would be generally admitted that compressed gas for buoys, beacons, and the like, was the best system that could be adopted for that purpose, because it had the peculiar advantage of enabling a large quantity of light-giving power to be stored in a small compass; but it was worth the consideration of engineers whether the system of generating gas from heavy oil by means of expensive gas-works was the best for the purpose of driving engines or giving light. No doubt, on a large scale, the use of gas-works for producing gas from heavy oil might be economically applied. The first cost was in all cases a very important consideration. In the case of Ailsa Craig the cost had been between £3,000 and £4,000, and the gas-works were employed to produce 32 HP. (four 8-HP. engines), and also to give a very small amount of gas for illuminating the lighthouse. The latter quantity was not very important, and therefore it might be taken for practical purposes that there was a production of 32 HP. by an apparatus which cost the large sum of money mentioned. It would, of course, never be argued that gas could be economically employed as a means of power; but for some purposes, particularly on places like Ailsa Craig, where engines were employed for fog-signalling, where the quick starting of the engine was an important feature, Mr. Ingrey.

Mr. Ingrey. and where gas was found to be preferable as a light, that source of power was undoubtedly the best that could be used; but it was a question whether the best and most economical method had been adopted in the case referred to. The Author had mentioned that from 20 to 30 cwt. of coal had been employed to produce 100,000 cubic feet of gas, and that quantity of gas could be produced from 100 gallons of oil which cost 4½*d.* per gallon, so that the cost of oil was 37*s.*, and of the coal from 20*s.* to 30*s.* According to the Paper, the cost of the gas was 5*s.* 9*d.* per 1,000 cubic feet, excluding the cost of delivery of the coal, of labour (a large item) necessary to operate the retorts, of the carriage of the oil itself, and of the large amount which ought to be set aside on account of the interest on the first cost of the apparatus and its depreciation. But that amount of HP. could be produced at less cost than for the amount of coal used in the retorts themselves. Taking 32 HP., which an ordinary high-pressure engine would give with 5 lbs. of coal per HP., it would be found that the required amount of HP. could be given with about 18 cwt. of coal. So that with 80 per cent. of the coal used to generate the oil-gas to produce power, that power could be given without the oil and without the gas-works. If that was not a good system, was there a better one? It was not, perhaps, becoming on his part to criticise a work with which he was so intimately connected; but he could hardly resist the opportunity of mentioning the figures, because he thought that were it not for the great advantages of the use of gas, the Commissioners of Northern Lights would not have adopted the system. He thought that the lighter forms of oil might with advantage be adopted for the production of power, at a much cheaper rate than by the system of evaporating or generating gas from heavy oils, because in the latter case a very expensive plant was necessary. A few weeks ago his attention was directed to the "Sheridan" apparatus, with which he had been much struck. It was well known that the use of lighter forms of oil had been in vogue for some time. Gasoline, or petroleum spirit, had been, and, he believed, was still employed for lighting dwellings, and for giving power for driving engines. The chief source of objection to it was found in the danger attending the storing of that light volatile spirit. For lighthouse purposes it was obvious that every precaution should be taken to ensure safety; a light intended to warn ships should not be liable to interruption; but it was impossible to ensure perfect safety in every instance, and where (as at different lighting stations where explosive signals were used) the storage of rockets, dynamite

explosives, and gunpowder for firing cannon was permitted, he imagined that with equal precautions a still less explosive material might also be used. He questioned, also, whether the danger of storing the lighter oil was greater than the danger attending the manufacture of heavy oil-gas by the retort process, and the storage of the gas so made in large gasholders. If by the little Sheridan apparatus exhibited, or any other equally efficient apparatus, gas could be manufactured at the point at which it was to be used, and in the same ratio at which it was consumed, without necessitating the storage of any explosive gas, then it appeared to him that the necessity of a heavy expenditure in plant would be obviated. He understood that the cost of the lighter form of oil would be three times as large as that mentioned by the Author, 1*s.* 2*d.* against 4½*d.*; but that lighter oil had less residuum, and would form at least twice the quantity of gas. It might be said that for making gas of a similar quality and for the same purpose as that used at Ailsa Craig, 200 cubic feet of gas could be produced for 1 gallon of oil; and seeing that there would be no fire, no coal, no furnaces, it would be fair to take the gross cost of that gas, per 1,000 cubic feet, at five times the cost of 1 gallon of oil, namely 5*s.* 10*d.* Taking the cost which the Author had mentioned at Broadness and other lighthouses, he presumed that 10*s.* per 1,000 cubic feet was the very least price at which it could be produced, so that the comparison was considerably in favour of the use of the light oil. In the one case an expenditure of from £3,000 to £4,000 was required to construct the works, and in the other case he was informed that between £200 and £300 would be necessary to produce the 32 HP. required. Mr. Ingrey.

Mr. W. Foster said he had been for some years interested in the gas question, and he felt somewhat nervous on hearing the remarks of Mr. Preece. He occasionally heard what engineers were doing in supplying electric light; and he had been informed that it was invariably attended with an increased consumption of gas for the purpose. They were also excessively disturbed by irregularities and other inconveniences. No doubt the latter would be remedied in time, and great progress was certainly being made in that direction. Leaving such matters, however, he would direct attention to an apparatus on the table, referred to by Sir Frederick Bramwell. It was one of the old spherical vessels used by the Portable Gas Company, alluded to by the Author. The gas was sent out to consumers much in the same way as by the present makers of oil-gas. He had been for several years busy with various substances (not oil or coal) Mr. Foster.

Mr. Foster. that required a little patience and ingenuity. Getting rid of the ascension-pipe, he had found a great relief. Some manufacturers of oil-gas used the descension-pipe, taking the gas downwards instead of upwards. In dealing with various substances, not so easy to work with as oil, he had avoided some of the difficulties to which reference had been made, and had been able to do things which would have been impossible with the ascension-pipe. He had inquired into the composition of the gases obtained by the distillation of oil. In February 1887, a friend in Scotland had sent him some oil-gases obtained in the distillation of petroleum. He examined them, and a short account of the inquiry was given in the Report of the Gas Institute last year on a Paper by Dr. Macadam on "Gas from Oil."[1] Since then he had had an opportunity of taking samples of oil-gas made by one of the manufacturers referred to in the Paper. It was a high-temperature gas, and differed considerably from the former. Oil-gas, made at low temperatures, contained a considerable amount of carbon-vapour. By heating the oil in retorts, gas was obtained which was as high, if not higher, in illuminating value. The amount of carbonic-acid gas, and therefore of carbon-vapour, which would be obtained by the combustion of 100 volumes, was much less in the case of high-temperature gas than in the case of low-temperature gas. If gas were obtained by saturating air in the way intended by the use of the apparatus exhibited, the amount of carbon-vapour would be very high, but the illuminating power would not increase in proportion. By the action of heat in the destructive distillation of oil unsaturated hydrocarbons were obtained, the energy of which, as an illuminating agent, was considerable. Berthelot had shown that benzene-vapour, acetylene, naphthaline, and other bodies, increased the illuminating power considerably: that 3 per cent. by volume of benzene would raise a non-luminous but combustible gas to the power of 20-candle gas. In the case of low-temperature gas, the total amount of carbon-vapour was high, and it existed largely in the form of paraffins. By heating in a retort at still higher temperatures such paraffins could be made to yield other substances, which had a high illuminating power: the heat energy was passed into the retort and took the form of molecular energy in the case of the new substances, which were raised in illuminating value. Dealing with gases produced at still lower temperature, he had no doubt that the total amount of carbon-vapour

[1] Transactions for 1887, p. 41.

would be found to be much greater. One point in connection with the analysis was the enormous difference observable in the amounts of $CO_2$ produced on combustion. 100 volumes of the low-temperature gas would give 150 volumes of carbonic-acid gas; the high-temperature gas would give considerably less. With regard to the petroleum-vapours, he had no doubt that their amount (speaking of the amount of $CO_2$ produced on combustion) would be considerably greater. Connected with that subject was the question of getting more illuminating value by the action of heat in the retorts. The question had been raised as to whether it was worth while to use high temperatures and expensive plant in that way. He did not know what would happen in that case; but he imagined that it would be expensive, and that a considerable amount of carbon would have to be put into such gas, to produce anything like the high illuminating value known to obtain in the case of gas made by destructive distillation proper. There was great merit in a machine of the kind referred to, because it was automatic, and the device certainly seemed a very good one. Petroleum-vapour acted as the motive power, it caused the piston to descend and the larger air-piston to ascend, and by that means the air and vapour were mixed. He could not (as Sir Frederick Bramwell had suggested) see how gas was being made. No tar was produced, and if petroleum-vapour was merely passing forward without the production of tar the first products were not being differentiated, but the spirit was merely caused to vaporize into the measured quantity of air, which was renewed from time to time by the machine automatically. Mr. Foster.

Mr. E. A. Cowper observed that a number of buoys and beacons were used in the Suez Canal, and a great many others in Holland. In the summer of 1884 he wrote to Count F. de Lesseps and to the English Commissioners, suggesting that the boundary of deep water in the Suez Canal should be outlined with baulks of timber on each side painted with luminous paint. He received in reply a polite letter stating that it would be too expensive. It appeared that there were now ninety-eight lights on the Suez Canal, twice as many as there were in Great Britain, six times as many as in Holland, and ten times as many as in the United States. The illumination of the canal, of course, made it far more valuable than it was before, as it could now be used at night as well as by day. Mr. Cowper.

Mr. R. H. Harland wished to refer to the question from a chemical stand-point; so far, the engineering details connected with the storage and use of the oil-gas appeared to be perfect, but Mr. Harland.

Mr. Harland. the apparatus for the manufacture of the gas had not been devised with the same attention to scientific detail; the apparatus described consisted simply of a retort with a tank for the oil, placed above. That was wrong from a scientific point of view, because, the seal being only a few inches in depth, there was always a liability of a sudden burst of gas destroying the seal, with consequent firing of the gas and oil. He should like to be informed as to the wear and tear of the wrought-iron retorts. Mr. Harland had had charge for some months of a small oil-gas factory for lighting a sugar-refinery abroad, where coal-gas could not be produced, and the difficulty experienced was the wear and tear of the retorts by the continual dropping of the oil. The Author had not stated whether the oil was dropped into the retort; but he presumed, from his reference to a micrometer cock for regulating its flow, that the action was a dropping one. In the case of the works he had referred to, the great difficulty was the prevention of pitting. After the retort had been in action for a short time the pitting was so extensive that a hole was speedily eaten through it, and then naturally the gas produced was burned, and a new retort had to be put in. He thought that Mr. Foster was under a misapprehension in stating that it was necessary that tar should result from the dissociation of low-gravity oil. In the refining of crude oil the object was to evolve as far as possible the whole of the tar produced by destructive distillation. The oil, used in the automatic machine described, had been refined not less than half a dozen times. It was therefore a pure hydrocarbon, so that, whether it was destructively distilled or evaporated at a high temperature, no tar could possibly result, because there were no chemical compounds in the substance likely to produce tar; consequently, the gas generally obtained from low-gravity oils was richer in illuminating power, and contained much less residual products, than gas produced by destructive distillation at the very high temperature used in the retorts described. It appeared to him that it only required an adaptation of the automatic machine, or a machine to work on the same principle to produce gas, not necessarily from gasoline, but from shale spirit and other spirits of that description, which were drugs in the market and could hardly be utilized. He thought there was a large opening for that class of oil, to be converted into gas at a low temperature, and utilized for the illumination of buoys or for driving engines to produce fog-signals.

Mr. Rickman. Mr. W. B. Rickman was glad that the subject of lighting railway-carriages had been introduced, because whether the work was done

by electricity or by oil-gas, every traveller was personally concerned in it. Pintsch's Lighting Company had lighted more than four thousand carriages in this country, and more than twenty thousand abroad. There were certain points that should be laid down as necessary. The light should be sufficient—not less than 10-candle power; each vehicle should be provided with a means of supplying light for from thirty to thirty-six hours, and should be independent of the others, so that the train could be broken up as might be desired, and should be capable of being charged with the illuminant in a reasonable time, say not more than two or three minutes, and the weight carried ought not to be excessive. He did not think that at present any system of electricity fulfilled those conditions. Storage batteries took a long time to charge. Provision had to be specially made with an under-frame for the heavy weight of storage batteries which had to be removed from time to time, or else the carriage had to be kept standing until the batteries were charged; or it would be necessary to invent a primary battery which would maintain five or six 10-candle lights for thirty or thirty-six hours. The battery had to be economically and easily managed, and the chemicals which supplied it should be easily renewed. Electrical science was no doubt making great progress, but up to the present moment the requisite conditions had not been fulfilled for the lighting of railway-carriages. Reference had been made to the system under trial by the North British Company for accomplishing the object by means of a centre rail. Of course, so long as there was a rail so long electricity could be obtained; but, as far as he knew, the company had only placed rails in certain Glasgow tunnels, and had made no provisions for lighting at night by electricity elsewhere. He believed that some carriages which had been arranged for electric lighting were now going to be fitted with Pintsch's oil-gas apparatus, because for night purposes it was necessary to light up the carriages on the whole line, and not have it split up by short lengths of rails. To have two systems of lighting the same carriage he thought would be objectionable. Allusion had been made to the danger of fitting railway-carriages with compressed oil-gas. He believed there was a danger in electric lighting owing to the covering of the wires giving way. Of course that could only be tested by practical work. There had been collisions with trains fitted with oil-gas on the Midland and on the Metropolitan railways. Quite recently a train fitted with oil-gas had run into another train on the Seacombe, Hoylake and Deeside line, on the day of its opening, and a most disastrous accident occurred, the carriages being considerably knocked about. One of Mr. Rickman

Mr. Rickman. the trains was lighted and the other not. No accident of any sort happened with regard to the lighting, nor could it happen, because the amount of compressed oil-gas carried was exceedingly small. It was the custom to light the locomotives of the North German State Railways with compressed oil-gas, and, what he thought was exceedingly dangerous, to place the cylinder upon the locomotive in close proximity to the firebox. It was clear that if an accident happened, and the oil-cylinder was injured by a fragment from the tire of a wheel, or anything of that kind, and if the stream of gas was directed into the firebox, or coal was thrown out, there must be a light, and if there chanced to be a guard's van, or anything else piled on the top of the locomotive, it must burn. He was surprised at such careful people as the Germans making such an arrangement. If the carriages themselves were fitted with the apparatus, and it was kept away from the locomotive, no danger would be incurred. Collisions had happened over and over again in this country with trains fitted with oil-gas, and no evil result had followed. It might be interesting to the members to know that the whole of the Suez Canal was now in process of being lighted with Pintsch's compressed oil-gas. In the straight reaches there was a white leading light at each end, and at distances of about 2 miles there were what he called gas-beacons, a cylinder filled with compressed oil-gas, and a lantern was placed upon a stand near it. They were red on the western side of the canal, and green on the eastern side. They were all fixed lights. At the curved parts in the Bitter Lakes, and also at Port Said, and Port Tewfik, there were many buoys which were simply used as guiding lights to enable the ships to take the necessary turns, it being impossible to work by leading lights as in the straight reaches. The matter had been carefully fought out by electricians and others. The first buoy was sent out to the Suez Canal in 1880, and others followed. A decision had been arrived at on the subject, and the whole arrangement was being executed, and would, he believed, be completed by the month of September. The Suez Canal was one of the most important water-ways in the world, and it would be interesting to Englishmen, who had 80 per cent. of the traffic there, to know that the canal was being lighted by an English company. The oil-gas system was still progressing, being in use in Servia, Brazil, Sweden, and elsewhere. Nothing seemed to affect oil-gas in the way of heat or cold. Some speakers had referred to very light oils, meaning, he thought, hydrocarbons, which flashed at a low temperature. Such oils were not only dangerous in themselves, and difficult of transport, but he believed

they were exceedingly uncertain, giving, for example, a very different result in Egypt from what they would in Canada or Sweden. He preferred an oil which was not a light one, which was reliable, and which would yield gas in any climate when distilled. Mr. Rickman.

Mr. CHARLES HAWKSLEY said, as to the question of lighting railway-carriages, he did not think that any of the lights referred to would give satisfaction, until those who had charge of the lighting refrained from stinting the illuminant for the sake of economy. Mr. C. Hawksley.

Mr. R. H. BRUNTON observed that while there might be great advantages in the use of compressed gas for the purposes of buoys, railway-carriages, and the like, he thought there was much in what was said of oil-gas that required elucidation. In the first place, he did not quite understand what the oil referred to really was. Crude oil, obtained from shale after one distillation, still retained all its lighter constituents, and would therefore flash at a low temperature. The Author stated that oil-gas was the product of heavy petroleum or shale-oil once distilled, having a specific gravity of about 0·840, and flashing at about 220° Fahrenheit. But once-distilled shale-oil not having been robbed of any of its lighter constituents flashed at a low temperature. To obtain an oil flashing at 220°, a series of fractional distillations was required. Mr. Keith, of Arbroath, used an oil known as "green oil," which was obtained from the soda-tar after it had done its work of purification, and which answered the Author's description so far as gravity and flash-point were concerned, but that could not be the oil he referred to. Assuming it to be once-distilled oil, there appeared what seemed to be a remarkable incongruity. Shale-oil was obtained by the destructive distillation of shale at temperatures of, say, 600° or 700° Fahrenheit. By adopting such temperatures, gas was produced, a great proportion of which was easily condensed into oil. According to the Author, that self-same oil, after only one distillation, which separated from it only a small quantity of carbon in the form of coke, was by exposure to high temperatures in other retorts again converted into gas, the great proportion of which was incondensable. In other words, the gas was purposely made condensable in the first instance, then converted into oil, and reconverted into gas, which was incondensable. That was a roundabout method, for which he failed to see, in a great majority of cases, any justification. By the direct treatment of the shale at a higher temperature—say the same as that applied to coal in gas-works, Mr. Brunton.

Mr. Brunton. from 2,000° to 3,000° Fahrenheit—he did not imagine there could be any doubt that gas of a similar quality to that got from the oil might be obtained, while the cost of production would be enormously reduced, and the efficiency of working greatly increased. The Author had pointed in a cursory manner to what Mr. Brunton thought would be a very serious defect in the making of oil-gas as described. He had stated: "In the manufacture of oil-gas, constant and careful watching is required. The heat must be uniformly maintained." And again: "The quality of the gas depends more upon the temperature at which it is distilled, than upon the quality of the oil." He did not say what the temperature was, or how uniformity was obtained, and information on those points was very necessary. In his experience of the distillation of shale, nothing had a greater effect on the character of the oil than the want of uniformity in the temperature of the retorts. It was not until manual stoking had been done away with that a really good oil was obtained. The same remark would apply to the conversion of oil into gas; but no information was given as to how the difficulty had been met. The Author had also stated that when 1,000 cubic feet of the oil-gas was compressed to 10 atmospheres, it deposited 1 gallon of hydrocarbon, and 4 or 5 gallons of tar. It would be interesting to know what was meant by hydrocarbon, because tar itself was a hydrocarbon, paraffin and naphtha were hydrocarbons, and there were very many other varieties of the compound. He should imagine that, for small isolated lighthouses, compressed gas would be a very efficient means of illumination, and for the illumination of buoys it would also be useful. The Author had described a seemingly very ingenious device, by which the gas burning in buoys could be extinguished at intervals, giving the appearance of a flashing light. It seemed to him that the application of that idea in practice would be likely to be fraught with mischief. The lenses used on buoys were necessarily rigid, and the focal plane of the light was always at right-angles to the axis of the buoy. But as it was an exceptional occurrence for any buoy to be upright, it would also be exceptional for the focal plane of the light to be horizontal. It would follow the movements of the buoy, and therefore, as often as not, the light would be lost to the mariner's sight. The chance of mistaking a fixed light for a flashing one was, under such circumstances, very probable, and he therefore regarded the idea as a dangerous one.

Mr. Hill. Mr. Alfred J. Hill said it was stated in the Paper that after the retorts had been properly heated gas was made at the rate of

$6\frac{1}{2}$ to 7 cubic feet per minute. Perhaps the size of the retorts would explain that statement; but having had a little experience in making gas by the Pintsch system, the figure seemed to him to be a very low one. He had found from 12 to 14 cubic feet to be the average. He had timed the production that afternoon, and had found it to be 20 cubic feet per minute with 10-inch retorts; and he believed that the quality did not deteriorate, being the same as that mentioned in the Paper. Could the Author give any information about the loss of illuminating power if the gas was compressed to more than 10 atmospheres? He had said that there was a loss of about 20 per cent. when the gas was compressed to 10 atmospheres. It was sometimes necessary to increase that pressure, and he believed that with a slight increase of pressure a great loss of light would be occasioned. He had endeavoured to compare by the Paper the cost of the Pintsch system with that of Pope, but he had not been able to obtain any very clear result. The cost of the Pintsch system with a candle-power of 5 was given at 0·09*d.* per light per hour, and the cost of the Pope system was given at 0·04*d.* He did not think that that was accurate; the cost of the two lights was, he thought, about the same. It was true that the candle-power was not given in the second case, and that might account for the difference. In the Appendix, the cost of the works for the production of gas was said to be very different. It would be advantageous to have some explanation of what was included in the cost, otherwise the statement was liable to be misunderstood. The cost of the Great Eastern Works was said to be £6,900. In that figure was included the cost of six pairs of travelling gasholders, which were necessary to convey the gas to the stations, also the cost of filling posts and pipes at five stations. Perhaps those items were not included in the other costs, and that might explain the discrepancy in the values given. He had been surprised that no remarks had been made in the Paper or in the discussion as to the use of the residual products, especially the use of tar as a fuel. At the Great Eastern Works tar was being used as a fuel for obtaining steam in the boiler which supplied steam to the compressing-engine, the tar being injected into the furnace by means of a special form of injector; and though that of course reduced the value which would be shown of the by-products, it also reduced the cost of making the gas. It was a great convenience. Two or three years ago tar became almost unsaleable, and at one time 4,000 or 5,000 gallons had been in stock, which could not be sold. That had led them to adopt it as a fuel, and it was a great convenience to be able to consume all the tar Mr. Hill.

Mr. Hill. made. Only the tar made on the premises was used, and that was not sufficient to keep the boiler in steam; it was therefore burned in combination with coal and solid fuel. He did not know whether the plan was adopted at other oil-gas-works, but he should think it would be very advantageous.

Mr. Barrett. Mr. S. R. BARRETT stated that previous to 1885 seven British railway companies adopted compressed gas for railway-carriage lighting; but it was compressed coal-gas. This was used as common 16-candle gas, enriched by means of gasoline, and enriched London cannel-gas of 20-candle quality was also used. The illuminating power of each quality after enrichment was raised to 40- to 50-candle quality. At present only one British railway company used compressed coal-gas; it had, however, been largely adopted in Germany and in America. To give some idea of the quantity of coal-gas burnt on railways, he might mention that the Jersey City Gas Company was paid £2,000 per annum by the New York and Quaker City lines for lighting their trains, the gas being supplied in a compressed form by the gas company. That compressed coal-gas was a suitable illuminant for railway-carriages was thus clearly established. Its discontinuance in this country was probably owing to its low illuminating power in an unenriched form, and to the variation of the illuminating power after enrichment. The chief cause, however, was the introduction of superior appliances by Messrs. Pintsch and Messrs. Pope, with their oil-gas systems. Since the discontinuance of coal-gas for railway-carriage lighting in this country, improved gas-burners of a regenerative type had been invented. These burners gave a 5-candle light per cubic foot of gas consumed, with common 16-candle gas; whereas the fishtail burner as now used for oil-gas, would not give more than 1-candle per cubic foot, with the same quality of gas. This fishtail burner yielding so bad a result was necessary for oil-gas, as other burners produced a yellow and smoky flame, and it seemed, therefore, that the quality of the gas had been raised to meet the deficiencies of the burner, rather than a burner sought that would give good results with a comparatively low quality of gas. In Scotland, where cannel-coal was very cheap, gas companies supplied the cities of Edinburgh, Glasgow, and Aberdeen with a rich coal-gas of 25- to 30-candle-power, at a price of 3*s*. to 4*s*. per 1,000 cubic feet. With that gas, cheap as compared with the oil-gas quoted by the Author, he thought it would pay railway companies to import cannel-coal-gas in a compressed state from Scotland. By that means, in conjunction with the improved burners referred to, a good light could be obtained for carriages at a small cost. It was

stated that 30-candle gas, when compressed to 90 lbs. to the square inch, would be reduced in illuminating power to 20-candle quality; but that would be still 4 candles better than the gas at present used in London. Such compressed coal-gas, burnt in a regenerative burner at the rate of 3 cubic feet per hour, would give a light of 20 candles per lamp, or five times better light than the ordinary average light from oil-gas in railway-carriages. The cost, with gas at 3*s.* 6*d.* per 1,000 cubic feet, would be at the rate of 0·12*d.* per lamp per hour. This would compare very favourably with the cost of oil-gas per light (0·209*d.*) per hour mentioned by Mr. Tomlinson, being nearly one-half. These new regenerative burners, from their general construction, and the position of the flame, seemed to have been specially designed for lighting railway-carriages. A burner of this type was tried for some months on the Great Western Railway four years ago, and gave great satisfaction; but the burners had never come into general use, nor had they been well known until recently. Another very economical way of burning compressed coal-gas for railway-carriages had been tried on the Belgian State Railways; Mr. Dery had burned common 16-candle gas in an enriched form, in carriages adapted for the oil-gas system. Each lamp was fitted with a carburetting cylinder containing naphthalene, somewhat on the principle of the albo-carbon gaslight. When the common gas was lighted, the heat vaporized the naphthalene, and the gas, in passing through the carburetter, became enriched to 50-candle quality, the same as oil-gas. This use of naphthalene seemed to have overcome many of the difficulties in enriching gas, as it was a perfectly safe carburetting material, and quite inert until brought into action by the flame beneath. Naphthalene solidified at 170°, and did not boil until 442° Fahrenheit was reached. A very small quantity of naphthalene was used, and the carburetters, which were made interchangeable, required charging only once in twenty days. The following was the result of trials with Mr. Dery's system of coal-gas of 16-candle quality, enriched with naphthalene. The cost of gas being 2*s.* 6*d.* per 1,000 cubic feet:— Mr. Barrett.

| | |
|---|---|
| Light given by lamp | 8 candles. |
| " " ordinary oil-gas lamp in general use | 4 " |
| Consumption of gas per hour | 1·5 cubic foot. |
| Naphthalene burnt per hour | 40 grains. |
| | *d.* |
| Cost of gas per lamp per hour | 0·05 |
| Cost of carburetting | 0·01 |
| Total cost per lamp per hour | 0·06 |

Mr. Barrett. This was a much less cost than for oil-gas, or any other system for lighting railway-carriages, and the system gave double the usual light from the best oil-gas lamps.

Mr. Ayres. Mr. Ayres, in reply to the discussion, observed that Sir James Douglass had shown that, although the first installation at Broadness cost 30 per cent. more than at Stoneness, the cost per unit of light per annum was only 6*s*. 3*d*., while at Stoneness it was 39*s*. The system at Stoneness possessed advantages where a cheap and feeble light was deemed sufficient for the special purposes of navigation. Referring to the points raised by Mr. Tomlinson, the oil-cistern was placed at the side, and not over the fronts of the retorts, and was probably safe in that position. It was so arranged by Messrs. Pintsch; he must, however, admit that the more remote from risk of accident the better. As regarded the pressure in the gasholder at Blackwall, it was correctly stated in the Paper. The yield of gas per gallon of oil at Ailsa Craig was stated to be as high as 100 cubic feet, as obtained by Keith's apparatus. From Mr. Tomlinson's practical acquaintance with the subject, he was able to speak authoritatively as to the consumption and cost per lamp per hour on the Metropolitan Railway. The figures quoted in the Paper were kindly furnished by the London and North-Western Railway Company. In comparing such figures, two important factors ought to be taken into consideration, namely, the relative illuminating quality of the gas, and the photometric intensities of the flames. Without this he failed to see how any accurate comparison could be made. The values of the residuals quoted were the actual figures furnished by the companies named. Several of the companies, to whom he had applied for information, had informed him that they did not then consider their statistics sufficiently reliable, as their works were in a state of transition. The use of mercury for filling up the clearance of the compressing-pump was certainly novel. The compressing-pump, as supplied by Pintsch's Lighting Company, reduced the clearance to a minimum. Tar was deposited inside the retorts, which was removed after three days' working. If this precaution were neglected, the deposit would seal up the ends of the oil-supply pipe, and cause the oil to overflow and take fire. In replying to Mr. Keith's observations, reference to Langness had been purposely omitted, as the subject of the Paper was compressed oil-gas and its applications, and he therefore only considered it necessary to refer to the more important installation of Ailsa Craig. The results obtained there were certainly almost unprecedented. He could not agree that the illuminating intensity

of gas was improved by mixing it with atmospheric air. With a Mr. Ayres. properly constructed burner this should not be necessary, the only mixture of the gas and air should take place at the point of combustion. He fully appreciated the remarks of Mr. Preece regarding the comparative values of gas and electricity as sources of power and light. The rapid strides made by electricity of late, pointed unmistakably to the important part it was destined to play in the future. In reply to Mr. Killingworth Hedges, the practice of carrying the gasholders under the carriages was by no means uncommon, and, he thought, was no more dangerous than in any other position. The holders contained only a small quantity of gas, and when a serious accident occurred the carriages were so completely destroyed that it would probably make but little difference whether the gasholders were attached to the roofs, or the under-framings of the carriages, as in either position they would be exposed to the same risk of coming in contact with the fire of the engine. Carrying the holders beneath the framing lowered the centre of gravity of the carriage, and contributed to steadiness in running, which was an important consideration. With regard to gasoline, or petroleum spirit, as a source of lighthouse illumination, although used at Stoneness, the quantity stored at that station was very small. It was stored in a fireproof and thoroughly ventilated store-room, the sides of which were plated internally and externally, with a free circulation of air between the plates, so that the internal plate did not become heated by the sun's rays. The reservoirs containing the spirit in the lantern were also cased with asbestos cloth, and no artificial light was permitted in the store-room. Such precaution being necessary, even on a small scale, evidently petroleum spirit would not be admissible for ordinary lighthouse illumination. The plan adopted for the storage of explosives in lighthouses and light-vessels was such that no serious mishap could occur, the detonators and cotton-powder charges being kept apart, and stored in proper magazines. The cost of gas at Broadness was decidedly moderate, taking into account the comparatively small quantity manufactured annually at the Blackwall works. As to the durability of the retorts in the works referred to in the Paper, they had lasted fully six months. Mr. Panter, of the London and South-Western Railway, stated that, in the manufacture of 2,696,760 cubic feet of gas, eighteen retorts had been burnt out. Pitting of the retorts had not been experienced in the works at Blackwall, the oil being received on sheet-iron trays, and not dropped directly on to the floor of the retorts. As pointed out by Mr. Rickman,

Mr. Ayres. one of the advantages of lighting railway trains by compressed oil-gas, was that each carriage carried its own supply; consequently the carriages were totally independent of each other, and could be detached at pleasure. With electricity, unless each carriage carried its own storage-accumulators or electrical generator, connection would have to be made from one carriage to another. This would be inconvenient when a train was broken up. The connections were already sufficiently complicated with couplings, gas-fittings, automatic brakes, and passenger cord, or electrical communication; but doubtless science would ultimately overcome this only difficulty in the application of electricity. The cost per burner per hour of Pope's and Pintsch's systems was, he should say, practically the same; but, without accurate tests to ascertain the richness of the gas and the efficiency of the burners, it was difficult to arrive at accurate results. The figures relating to consumption and cost had been obtained with as much care as possible, and were practically correct. He had to thank Mr. Rickman for information kindly furnished in regard to the lighting of the steam-ship "Ireland," and other Irish Channel mail steamers, by compressed oil-gas. Mr. Brunton had raised several questions relative to the kind of oil used in the manufacture of oil-gas. The figures given in the Paper, as also the description of the oil, were, as far as he knew, correct. The oil was of a yellow colour, the refuse of paraffin, and was obtained from the Scotch oil distillers. The advantages of Mr. Brunton's subsequent suggestions must depend upon experiment for their elucidation. The mode of manufacture described in the Paper was that adopted at the works particularly referred to, which were upon Pintsch's system. The temperature of the retort was from 1,650° to 1,800° Fahrenheit. To prevent the possibility of choking, reasonable care was necessary, otherwise the gas would not circulate as freely as it should do, through all the parts of the apparatus, until finally delivered into the gasholder. It did not therefore appear unreasonable that proper care should be taken to ensure the efficiency and safety of the process. The term hydrocarbon, as applied to the product resulting from the compression of oil-gas, was a mere commercial name. The fluid was really a complex mixture of hydrocarbons. It contained benzole, or, as it was called in science when pure, benzene = $C_6H_6$. This hydrocarbon was the source of the so-called aniline colours. The fluid also contained hexyline $C_6H_{12}$, heptyline $C_7H_{14}$, and some other hydrocarbons. The term, therefore, appeared consistent. The figures quoted in the Paper, as to the rate at which oil-gas

was produced, were the results obtained at Blackwall. It did not necessarily follow that they applied to all other works. It was distinctly stated that the greater the production or output, the greater the efficiency and economy. He had no data regarding the loss of illuminating power arising from compression beyond 10 atmospheres, but understood it was considerable as the pressure increased. In making a comparison of the cost of oil-gas manufactured on different systems, it would be necessary to know the illuminating value of the gas, and the description of the burners used, which, for the purpose of experiment, should be exactly alike, and interchangeable while under trial. Mr. Ayres.

## Correspondence.

Mr. G. Beilby stated that, having had control over the manufacture of gas-oil supplied to the Metropolitan Railway Company, in 1879 and the following years, while this system of lighting was in its infancy, he had instituted a number of laboratory and manufacturing tests to determine the most suitable oils, and the best temperatures at which to decompose them into illuminating gas. The results of these tests were generally in accord with the conclusions of the Author. It was found that the so-called "intermediate oils" of the Scotch refineries were very suitable, especially the portions with a specific gravity of about 0·840. These "intermediate oils" were so called because in boiling-point and specific gravity they ranked between burning oils on the one hand, and lubricating oils on the other. Owing to the very limited demand for oil of this specific gravity, its price was generally much below that of either burning or lubricating oil. The comparatively low price of so suitable a material no doubt helped to bring about the prompt adoption of oil-gas lighting by railway companies. The price of burning oil, in 1879, was about 10*d.* per gallon, or equal to 10*s.* per 1,000 cubic feet of oil-gas. With cheaper oils, at from 3*d.* to 6*d.* per gallon, the cost for oil would be from 3*s.* to 6*s.* per 1,000 cubic feet. As regarded the plant for oil-gas making, and the system of manufacture, the present forms and methods, as described by the Author, seemed to be thoroughly practical and satisfactory; but a study of the chemistry of the subject showed that there was still room for improvement, so that a richer and more permanent gas might be obtained. In 1887 attention was directed to certain waste gases Mr. Beilby.

Mr. Beilby. from the stills of Scotch oil refineries,[1] which were of high illuminating power and fair permanence, and which might, to a considerable extent, replace specially manufactured oil-gas, at any rate on local railways.

Mr. Botley. Mr. C. E. BOTLEY was disappointed that the Author had dealt so briefly with the manufacturing details, which varied so much in different works, and which were comparatively unknown; and also with the utilization of the resultant products, a matter of supreme importance, as affecting the cost of production. With regard, again, to the oil used, from a considerable practical experience he would venture to controvert the Author's statement that "the quality of the gas depends more upon the temperature at which it is distilled than upon the quality of the oil." The quality and quantity of gas produced were both affected by the temperature at which it was distilled from the oil, and every oil required a different treatment to obtain the best results. A fair comparison of the quality of the oil could be obtained by multiplying the ascertained illuminating value of 1 cubic foot by the number of cubic feet of gas produced from 1 gallon of oil. The gas should be tested with a flat-flame burner, not an argand. The figures given in the Appendix, respecting the quantity of gas produced per gallon of oil were valueless unless the illuminating value was stated; this was also affected by the basis on which the oil used was calculated. If the actual quantity used in the retorts was only mentioned, it would necessarily give a high yield of gas; but if the quantity used was calculated from the variation in stock from one week to another, it would make an appreciable difference, as there was a loss of about 6 lbs. per cask from absorption, &c., besides leakages from tanks, and in pumping, &c. The Table on p. 351, made on this basis, of some extended trials of different gas-oils, showed how they might vary, both as regarded quality and value for gas-making. He contended that, after efficient condensation and scrubbing, oil-gas did not require any purification, as the only impurity detectable was the faintest trace of $C\,O_2$, but possibly the dry lime purifier did some good as a dessicator for the gas. The pressure on the retorts (as no exhauster was used) should be reduced as much as possible by counterbalancing the gasholder. A pressure of 3 inches of water there was certainly too much for satisfactory working. An excellent plan was to have an electrical contact on the guides of the gasholder, communicating with a bell in the compressing engine-room, to attract the attention of the

[1] The Journal of the Society of Chemical Industry, vol. vi. p. 31.

PRACTICAL ANALYSIS of GAS-OILS.

Mr. Botley.

| Description of Oil. | Specific Gravity. | Cubic Feet made per Gallon of Oil used. | Illuminating Value of 5 Cubic Feet Compressed. | Grains of Sperm per Gallon of Oil. | Cost per Gallon. | Cost (of Oil) per 1,000 Cubic Feet of Gas made. | Comparative Cost. |
|---|---|---|---|---|---|---|---|
| | | | Candles. | | d. | s. d. | |
| American | 0·835 | 71·5 | 45·0 | 77,220 | 3·80 | 4 5 | 492 |
| Welsh . | 0·857 | 72·5 | 46·0 | 80,040 | 4·126 | 4 8·9 | 515 |
| Shale . . | 0·854 | 76·0 | 45·0 | 82,080 | 4·92 | 5 4·75 | 600 |
| American | 0·832 | 74·24 | 45·0 | 80,179 | 5·845 | 6 6·6 | 728 |
| Scotch . | 0·844 | 72·6 | 36·45 | 63,510 | 4·850 | 5 6·8 | 763 |
| American | 0·846 | 74·0 | 38·45 | 68,280 | 6·0 (*a*) | 6 9 | 878 (*b*) |

(*a*) Out-of-pocket cost on rail. (*b*) Grains of sperm per gallon × gallons of oil per ton (determined by sp. gr.), striking off three last figures ÷ result into pence cost per ton of oil, striking off first decimal place.

driver, and showing on a disk when the holder was full or empty. This was the more necessary at night, and to prevent waste when full, or pulling in the crown of the gasholder when empty, as the holder used need only be of small capacity. The loss of illuminating power in oil-gas, when compressed, should not exceed 10 per cent., not 20 per cent., as stated by the Author; the loss was in direct proportion to the amount of carbon in the gas. From a long series of experiments which he had made on this subject, and communicated in a Presidential Address to the Southern District Association of Gas Engineers and Managers, in 1885, it was shown[1] that the lower the quality of the gas, the greater the power it had for re-absorbing the hydrocarbon deposited in the process of compression, as the pressure was reduced; consequently coal-gas did not lose so much in proportion as oil-gas. In oil-gas making the value of the products, viz., hydrocarbon and tar, had fallen off so much that it seriously affected the relative cost of production. A few years ago 1*s*. 3*d*. per gallon was obtainable for hydrocarbon, and 2*d*. or 2½*d*. for tar; but now hydrocarbon only realized about 6*d*. per gallon, and the tar was unsaleable. The tar was totally distinct from coal-tar, and contained a large portion of fine carbon grit in suspension. On distillation it produced a small quantity of heavy oil, which, however, was comparatively worthless for gas-making

[1] The Journal of Gas Lighting, &c., vol. xlv. p. 291.

Mr. Botley. again. After various trials under the retorts, as fuel, &c., at the works under his charge, it was successfully used for firing a large stationary boiler of the locomotive type, generating steam for the compressing engines, &c. The tar, which was highly inflammable, was admitted into the firebox by being blown in with superheated steam on to a baffle of firebricks laid dry, and, after once starting, it gave little trouble, the whole of the tar being used up in this manner. The hydrocarbon seemed to have but one use, being sent to Belgium to carburet coal-gas of low illuminating values. As regarded the quantity of oil-gas available for lighting, calculated on the amount registered by the meter as made, this would vary according to the conditions. If the gas had to be sent from the works in travelling recipients, to fill coaches at another place, 20 per cent. would be a fair allowance for losses in various ways. In the Appendix to the Paper, the cost of works for oil-gas making was evidently calculated on different bases, and if the comparison was made on the number of coaches fitted, the discrepancy was still greater. The Metropolitan showed a capital expenditure of £1,062 per 1,000,000 feet of gas made, and this would seem from experience to be a fair figure to take for works of a similar magnitude. No doubt oil-gas making, worked on a fairly large scale, was the best means existing for lighting railway-carriages, as also the least liable to failure; but there were instances where compressed coal-gas could be successfully applied, although the cost of fitting the coaches was increased by the extra storage capacity and weight of the cylinders to be carried. The cost of special works was, however, avoided, and where the cost price of the gas was taken as a comparison, there was no doubt of it being cheaper light for light. The Post-office mail-vans running between Gloucester and New Milford had been lit in this way for some years, and had worked fairly satisfactorily, the gas being used in regenerative lamps. Any system of gas-lighting was cheaper than oil, and far more satisfactory; but some of the railway companies, who had carriages fitted with gas, did not avail themselves of the better lighting at their command, but seemed to be content to give only the same amount of light as an ordinary oil-lamp, by keeping the gas turned down. An ordinary compartment of a coach having one lamp, consuming from $\frac{7}{8}$ to 1 cubic foot of oil-gas per hour, would yield a satisfactory and cheap light, and far superior as regarded diffusive power to any ordinary electric glow-light. The following Table showed the comparative cost of the oil- and gas-lights for actual and equal light:—

Mr. Botley.

TESTS of OIL and GAS RAILWAY-CARRIAGE LAMPS.

| Description of Lamp. | | Illuminating Value. (*a*) | Consumption of Oil per Hour. | Actual Cost of Oil per Hour (Light only). (*b*) | Consumption of Oil per Candle of Illuminating Value. | Consumption of Oil per Hour to give same Light as Oil-Gas. | Cost per Hour for equal Light (9 Candles). | Remarks. (*b*) |
|---|---|---|---|---|---|---|---|---|
| | | Candles. | | *d.* | Grains. | Grains. | *d.* | |
| Oil | 1 . . | 3·2 | 372 grains | 0·156 | 116·4 | 1,047 | 0·440 | Oil 27*s.* 6*d.* per cwt. Lamps burning to point of smoking. |
| | 2 . . | 2·3 | 231 „ | 0·097 | 100·4 | 903 | 0·380 | |
| | 3 . . | 2·6 | 295 „ | 0·124 | 113·4 | 1,020 | 0·430 | |
| | | | GAS. | | | | | |
| Gas | Oil-gas | 9·0 | 1 cub. foot | 0·100 | .. | .. | 0·100 | Gas 9*s.* per 1,000 c. f. |
| | Coal-gas (regenerative lamp). | 12·0 | 3 „ feet | 0·045 | .. | .. | 0·033 | Gas 1*s.* 3*d.* per 1,000. (cost price). |

(*a*) All naked lights, and taken from flat side of flame (except regenerative lamp). The edge of flame gave about one-third less light. (*b*) The relative costs were all based upon the usual mode adopted by railway companies, of taking the out-of-pocket cost only, the company manufacturing both oil-gas and coal-gas.

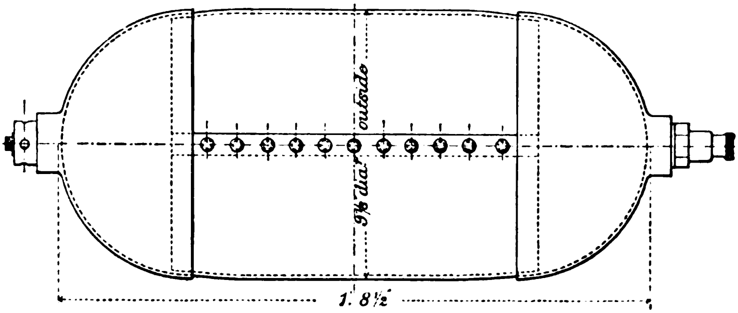
The above Table gave the actual cost of the illuminant used only; no allowance was made for trimming, waste, breakages, &c., which, of course, would show an enormous advantage in favour of gas. The use of compressed oil-gas had also been extended beyond the examples given by the Author, in the lighting of tramcars, omnibuses, and short-journey steamers, in all of which it had proved satisfactory, and there were no doubt many other cases in which it could be profitably and successfully applied.

Mr. G. BOWER remarked that a quarter of a century ago he supplied the Indian Government with an oil-gas apparatus for Rawul Pindee, which produced continuously, in the regular course of manufacture, 100 cubic feet of gas per gallon of native oil. Such a result, as would be seen from the Paper, was not now being obtained. In the first edition of his "Gas and Water Engineers' Book of Reference," published in 1866, he described a mode of compressing gas and applying it to the lighting of railway-carriages. He had thus been the pioneer in railway-carriage lighting. The Great Northern Railway Company had a train fitted up suitable for ordinary 16-candle gas, which was compressed Mr. Bower.

Mr. Bower. to 150 lbs. per square inch. Mr. Oakley did not want to have to erect special oil-gas works, but preferred to use common gas, and to have it carburetted on the carriages; but there were considerable difficulties with this system, and, although the train was still running, yet this mode of lighting was not developed. The regulator devised by his son Anthony reduced the pressure of the gas from the reservoirs to about 1-inch column of water, which never varied at the burner, no matter to what extent the pressure in the reservoirs might vary. Electricity for the lighting of railway-carriages was likely to supersede both oil and gas.

Mr. Dean. Mr. W. Dean remarked that twelve carriages on the Great Western Railway were fitted with apparatus for burning ordinary coal-gas compressed to about 8 atmospheres; they had been working with

Fig. 2.




Gasholder.

Proved and warranted to 30 atmospheres.

fairly satisfactory results. In view, however, of the rapid progress which was being made in the improvement of electric lighting, the Directors of that railway were not at present disposed to make any great extension of the use of gas. It might not be without interest to mention that, under the direction of the late Mr. Brunel, some experiments were tried about the year 1845 with coal-gas compressed to 30 atmospheres. It was carried in small reservoirs (Fig. 2). Unfortunately he had not been able to find any complete record of the experiments; but he had been informed that great difficulty was experienced in regulating the supply of gas to the burners, arising, no doubt, from the very high pressure employed.

Mr. Gladstone. Mr. S. H. Gladstone, with reference to the oil-gas system in

use at Stoneness Lighthouse, which had been installed for the Trinity House in December, 1885, observed that the Author was mistaken in saying that the number of flashes or occultations could not be regulated. The revolutions could be regulated to a nicety by simply altering the angle at which the blades of the fixed propeller or fan were placed; the following instance would, he thought, prove this. A year ago he put up two of these lights for the European Commissioners of the Danube at Sulina, one fixed, the other revolving. He was instructed to make the latter to show a green light for one second and a half; occultation for one second and a half; white light for one second and a half; occultation for one second and a half, and so on, producing alternate green and white flashes. The propeller was arranged accordingly, and when the light was set going at Sulina, it was found to give flashes and occultations of precisely the required duration. However, he did not himself consider that for such lights as these such very great accuracy in the number of revolutions per minute was needed. They were sixth-order lights, intended chiefly for harbour and for river purposes, and in these circumstances the pilots rarely had any length of time during which to observe the light. Whether the light gave ten or twelve flashes per minute was a matter of little moment to them; all they cared about was that the light should be distinguishable clearly by its flashes from the surrounding ship or shore lights, and thus all chance of their mistaking the one for the other be removed. Where several of these lights were shown in close proximity, they could be easily distinguished and identified, by placing red, green, or white glass in the revolving portion, and thus producing red, green, or white flashes, and forming a better distinction than by a slight variation in the number of flashes or occultations. As regarded the cost of this system, he thought it would be considerably cheaper than any other, both in first cost and in annual maintenance. The latter was covered by some £35 or £40; viz., £20 for oil, £5 for carriage and sundries, and £10 to £15 for the attendant to visit the light once a week, or once a fortnight. This man, it must be remembered, need not be a specially-trained light-keeper, but might be any ordinary person living near the light who had other regular daily work and means of livelihood. In Sweden, where many of these lights were in use, the nearest peasant was employed at a few shillings a year. In first cost, too, this system had a very great advantage over others, as there was no necessity for a large sum to be sunk in plant, as was the case with Pintsch's gas, for instance. The great majority of harbour-boards were Mr. Gladstone

Mr. Gladstone. unable, even if they were willing, to raise and expend a large amount of capital in costly plant, and to incur the heavy annual expense attached to such works; and it was of the greatest importance to them to be able to lay their hands on a cheap but reliable and efficient system of lighting. Lyth's burners had also been applied successfully for lighting buoys, giving a light of about 18 candles without lenses. The French lighthouse authorities had had these burners lighted for seventy days and nights without attention.

Mr. Greville. Mr. H. LEICESTER GREVILLE stated that he had had considerable experience in the experimental manufacture of oil-gas, and as the method he now employed differed somewhat from that described by the Author as used under Pintsch's patent, he would give a brief description of it. He found that 50-candle gas could be easily and continuously made by the simple expedient of allowing the oil to flow down a wrought-iron pipe, which, passing through the mouthpiece of the retort, extended to within six inches of the end. The oil vaporised in this pipe, and the oil-vapour suffered decomposition in passing back in contact with the heated sides of the retort to the ascension-pipe. The best heat was the ordinary temperature used on a gas-works, namely, a "cherry red," and the oil was ordinary common American petroleum. The gas was obtained at the rate of about 90 cubic feet per gallon of oil, and improved results were procured by using a little water or steam with the oil. The quality of the gas, and the number of cubic feet of gas obtained per gallon of oil, depended on the heat of the retort and on the rate at which the oil was run in. The best results followed with least back-pressure at the retort. The light of such rich gas as that of 50-candle power could not be estimated in the Sugg London Argand, the best plan being to consume it at a diminished rate of from 1·5 foot to 2 cubic feet per hour in a burner with fine holes, such as a No. 0 or No. 1 Bray, and then calculate the light to a 5-foot consumption.

Mr. Hanbury. Mr. J. J. HANBURY remarked that, in the case of the Metropolitan Railway, the value of residuals, referred to in the Appendix to the Paper, had varied considerably, hydrocarbon having been sold as high as 1*s*. 6*d*. per gallon, and as low as 6*d*. In regard to the general question of the application of oil-gas, he had fitted one of the Metropolitan Railway Company's omnibuses with the apparatus about eighteen months ago, and it had proved very successful. The omnibus was on the Portland Road and Charing Cross service, and was fitted with a reservoir,—in which gas was stored at 90 lbs. pressure per square inch,—and with a regulator and two burners.

The light was a great improvement upon the ordinary oil-lamp, of which complaint had been made. There was no flickering or jumping of the flames through the jolting of the omnibus running over stones or a rough road; and he believed it to be the only omnibus running which was lighted with gas. Mr. Hanbury.

Mr. G. M. HUNTER considered it would have been an advantage if the Author had given the volume of oil flowing into the retort per minute, which produced gas at the rate of 6½ to 7 cubic feet per minute. It seemed a very low production. It would likewise have been an advantage to have had the yield per gallon of oil. The water-pressure appeared too high; it was only when the retorts were dirty that the pressure rose to 5 or 6 inches; the normal pressure should be from 3 to 4 inches. It was doubtful if the gas suffered a loss of 20 per cent. in illuminating power by compression; under ordinary circumstances 10 per cent. was about the actual loss. Contrasting the Pintsch system with those of Pope or Keith, he might observe that with the Pintsch system every stage of the manufacture was mechanically controlled, and nothing in the way of a stoppage could occur without the attention of the attendant being directed to the place. Whereas in the Pope, and especially in the Keith system, no means were provided whereby the progress of the manufacture could be ascertained, or even the volume of gas made, unless by observing the rate at which the gasholder rose,[1] and multiplying the number of rivets by a factor obtained in proportion to the diameter of the gasholder. The systems of Pope and of Keith also lacked a very important part of the requirements of an oil-gas-work; they had no purifier. Gas, as made from oil, contained a varying percentage of sulphur compounds and carbonic acid which formed undesirable products in the gas. Independent of the question whether or not these compounds were injurious or unimportant in gas for the purposes of lighting buoys or railway-carriages, the presence of a thick layer of tar on the surface of the purifying tray, after one week's work, proved that the gas did require purification. It was evident that, in the event of no purification, the pipes and fittings of the carriages being only $\frac{3}{16}$-inch bore, must soon be clogged with tar. Another feature in Pope's system was that the oil entered the lower or hottest retort first, and passed out through the upper or colder retort. The efficiency of this arrangement was very questionable, Mr. Hunter.

[1] Transactions of the Institution of Engineers and Shipbuilders in Scotland, vol. xxx., p. 239.

Mr. Hunter. because the oil being delivered on to the hot retort would be distilled at once, and could not benefit much by the further passage through the colder retort. Not only so, but it was obvious that the consumption of fuel per 1,000 cubic feet of gas manufactured must be much greater, owing to the constant stream of oil lowering the temperature of the retort. In this way it resembled the Keith system, in which there was only one retort having a V shaped depression in the centre purposely to augment the distillation of the oil. Dr. Macadam said "that the length of heating surface in these retorts was not sufficient for the economic formation of permanent gas."[1] In the Pintsch system the oil was first delivered to the upper retort, where it was partially vaporized, and, passing to the lower or hottest retort, it was rendered permanent or "fixed," having travelled over about 11 feet 8 inches (10-inch retort) of heated surface.

Mr. Rowan. Mr. F. J. Rowan said the use of oil-gas in the compressed state possessed great interest, and had been dealt with by the Author in a succinct but satisfactory manner. It was not improbable, however, that, as he remarked, it would ultimately be displaced by electricity. As oil-gas was used in many places as a convenient illuminant without compression, its manufacture was important as affording an outlet for "intermediate" oils and other products of oil-works; besides which it was allied to the subject of liquid fuel, and it was in this view that he was particularly interested in it, believing that it contained the key to that subject. In addition to the methods of manufacture mentioned by the Author, there was another more akin to the mode of employing liquid fuel, but which also deserved notice for other reasons. This method consisted in injecting oil into red-hot retorts by means of steam-jets, the other portions of the apparatus remaining substantially the same as those described by the Author. It possessed the economic advantage of preventing to a great extent the deposition of solid carbon in the retorts, as the steam and the carbon of the oil reacted on one another, and by mutual decomposition added to the volume of the gas generated. The steam was conveniently produced by waste heat escaping from the retort furnace. The simplest form of this apparatus was found in the oil-gas plant manufactured by Rogers, of Watford. Methods of producing oil-gas for heating operations somewhat similar to this had been introduced by Colonel Foote, Messrs. Simm and Barff,

[1] The Gas Institute, Transactions for 1887, p. 45.

Dr. Eames and Mr. Dorsett,[1] in the past; and more recent plans were to be found in the "thermogens" tried at the works of the Norway Steel and Iron Company, Boston, U.S.A,[2] the apparatus proposed by Mr. B. H. Thwaite,[3] and the arrangement introduced by Mr. J. B. Archer, of Washington, U.S.A.[4] Whatever might be the form of apparatus ultimately adopted for the utilization of oil for heating, he was convinced that it must provide for the complete production of gas from the oil along with steam. The following considerations seemed to him to establish that conclusion:—Although the quantity of gas produced from 1 gallon of oil in Pintsch's apparatus was, as the Author remarked, about 90 cubic feet, Messrs. Rogers produced about 120 cubic feet per gallon; and Professor Armstrong[5] stated that from 90 to about 150 cubic feet had been obtained, whilst about 6 gallons of tar and hydrocarbon liquid were recovered per 1,000 cubic feet of gas made. Suppose that all the oil, including the residual liquid, was made into gas with steam at a high temperature, the total quantity of gas produced per gallon of original oil would not be far short of 250 to 300 cubic feet. The thermic value of this gas could be approximately calculated from its chemical constitution. Messrs. Rogers gave the following as the analysis of the gas made by their apparatus from an intermediate oil-flashing at 250° Fahrenheit:— Mr. Rowan.

| | |
|---|---|
| Oxygen | 0·73 |
| Nitrogen | 5·06 |
| Luminiferous hydrocarbons | 16·29 |
| Marsh gas | 46·17 |
| Hydrogen | 31·61 |
| Carbonic Oxide | 0·14 |
| | 100·00 |

Assuming that the luminiferous hydrocarbons mentioned were ethylene of the composition $C_2H_4$, the following statement gave the thermic value of this gas, which was said to be of 56-candle power; although if the composition $C_3H_6$ were assumed for

[1] Minutes of Proceedings Inst. C.E., vol. xl. pp. 150–161; xlii. p. 336; lii. p. 177, &c.

[2] "Iron Age," November 22, 1883. "The Journal of the Iron and Steel Institute," 1883, p. 749. "Iron," vol. xxiv. p. 54.

[3] "On Liquid Fuel; its advantages for firing steam generators." London. Spon.

[4] Chemical Technology, "Fuel," 3rd edition. p. 302.

[5] The Journal of the Society of Chemical Industry, vol. iii. p. 462.

Mr. Rowan. these hydrocarbons the heating power would be considerably higher:—

| | |
|---|---|
| Evaporative power of gas per lb. . . . . . . . . . | 40·75 |
| " " " cubic foot. . . . . . . | 1·622 |
| Fahrenheit heat-units per lb. . . . . . . . . . . | 21,843 |
| " " " cubic foot. . . . . . . | 869·3 |
| Calculated specific gravity of gas . . . . . . . . . | 0·4941 |

Taking 25 to 27 cubic feet of such gas as the quantity produced per lb. of oil, on the supposition that all the liquid was turned into gas with steam, it would be found that its thermic value was equal to the evaporation of from 40·5 to 43·79 lbs. of water per lb. of oil. This was not the highest result attainable, for it had been shown[1] that gas of 60- to 70-candle-power might be obtained from oils of 0·800 to 0·870 specific gravity, if properly treated. He thought, therefore, that it might be concluded that it was possible with suitable apparatus, using steam and wholly converting the oil into gas, to obtain continuously evaporative results with oil as fuel, exceeding four times the duty of coal weight for weight.

Mr. Stevenson. Mr. D. A. Stevenson observed that the introduction of Pintsch's system of lighting buoys and beacons was an important step in coast illumination. Of course, the manufacture of gas from oil was an old story, and the compression of it for conveyance to a distance was not new; but before it could be applied to lighting buoys and beacons, exposed as such structures were to winds, heavy sprays, and wave-shocks, great difficulties had to be overcome in the design of the buoy itself, the lantern which protected the light, and the breaking down of the pressure by a reliable regulator. These difficulties had been successfully overcome, and great credit was due to Messrs. Pintsch for the way in which they had perfected their system. The Clyde Lighthouses Trustees, who had always shown themselves ready to take advantage of improvements, were the first authority, in this country at least, to make a complete installation. This was in 1880, Roseneath Patch being the first of their buoys which was lighted; and there were now under their jurisdiction six lighted buoys and beacons. Besides this they supplied gas from their works at Port Glasgow, to eight buoys and beacons belonging to the Clyde Trust. Previously, however, the Trinity House, and the Dundee Harbour Trust, had made experiments with Pintsch's buoys. Mr. Cunningham,

[1] The Journal of the Society of Chemical Industry, vol. vi. p. 199; vol. vii. pp. 195–200.

Engineer to the latter board, had consulted Messrs. Stevenson in March, 1879, as to meeting two great difficulties he had found, namely, some mode of preserving the verticality of the buoy, as the pitching in the sea took the light out of the mariner's view, and also some method of distinguishing one light from another. To obviate the first of these difficulties, it was suggested that gimbals might be tried, and a design was made out but had not been executed for want of funds. As regarded the difficult problem of distinguishing one buoy from another, it was far from desirable to apply clock-work; and it occurred to the late Mr. Thomas Stevenson, M. Inst. C.E., to make the flow of gas produce automatic intermittent action by means of a dry gas-meter. Such a form of meter must always pass a sufficient quantity of gas to secure the constant burning of a small jet, situate either immediately above or in the socket of a larger burner provided with a separate tube, for giving at regular intervals an increased supply which went to the main burner, and was there ignited by the small jet. The full flame continued to burn until the action of the meter cut off the larger supply, and the small jet was again left burning alone. This process would of course go on continuously, so long as the gas in the buoy was not exhausted. Messrs. Milne, gas engineers of Edinburgh, were applied to for their assistance in the matter; and they, by altering the valves in a dry meter, made it answer perfectly all the requirements. This meter was sent to Pintsch's Company in 1879, and realizing the advantage of being able to distinguish one light from another, that Company subsequently (in 1883) brought out and patented the flashing arrangement described in the Paper. The Author had referred to the works which were designed and carried out by Messrs. Stevenson, at Ailsa Craig lighthouse and fog signals, where gas from mineral oil was employed, the gas being made by Keith's process. The advantage of Keith's process was, that the first cost of the apparatus used was less than that of Pintsch's, and it was quite as efficient. The Author had not referred to Langness fog-signal station, also designed by Messrs. Stevenson for the Commissioners of Northern Lights, and which was the first lighthouse station where mineral oil-gas was made. Experiments were carried out at Edinburgh, in 1879, to determine the capabilities of mineral oil-gas for driving gas-engines, and these experiments being successful it was determined to use mineral oil-gas at Langness, as being not only more easily manufactured than coal-gas, but also more economical at a lighthouse station, where freight and the cost of landing materials were serious considerations. Mr. Stevenson.

Mr. Wigham. Mr. J. R. WIGHAM observed that gas from oil, as the Author had said, was made long ago, and was supplied in a compressed form as portable gas in Brussels and other cities day by day, very much as milk was now delivered to its consumers; but it was soon found that the cost of this kind of gas, as well as the inconvenience of delivery, was such as to prevent its general adoption, and coal-gas then, as now, completely superseded it. The record given by the Author of the several patents granted for this kind of gas was interesting and instructive, and not only threw light upon the question itself, but showed clearly the noteworthy fact that, in this country, patent after patent could be granted for substantially the same invention. The method of producing oil-gas was practically the same now as it was twenty years ago; and the means by which compressed gas was reduced to a proper pressure for burning, were also practically the same. The Author had described the effect produced upon oil-gas by pressure, namely, the conversion of a considerable portion of its bulk into liquid hydrocarbon. This, of course, involved considerable waste, unless a high price could be obtained for the liquid, a consummation seldom realized. For lighting railway-carriages, and for buoys, compressed oil-gas, especially now that cheap crude petroleum could be used, was, as the Author had shown, a very practical purpose to which that kind of gas might be applied; but for important, or for any lights, whether for lighthouses or other purposes, where uniformity of illuminating power was required, he had found compressed gas to be utterly unsuited, chiefly on account of the extreme care which must attend the manufacture of the gas, the fires having to be kept at a uniform heat, and the quantity of oil introduced into the retorts regulated to a nicety. In practice, the cooling effect of the introduction of oil into the retort was such as to cause difficulty, for if the heat was raised sufficiently to resist this cooling effect, the illuminating power of the gas was to a large extent destroyed, and an incrustation of solid graphite covered the interior of the retorts and trays; again cooling down the apparatus, and adding to the difficulty of maintaining a uniform temperature. In 1865, at the request of the Commissioners of Irish Lights, he lighted Howth Bailey lighthouse with oil-gas; but it was soon found that, for the reasons above given, it was much better to use gas made from rich cannel-coal; and that lighthouse had been lighted with cannel-gas since that time. Of course, the quality of gas from cannel-coal was also affected by the heat at which the coal was carbonized; but the variation was not such as to be perceptible

in the ordinary fine jets with which such gas was burned. With oil-gas, on the other hand, the variation was often so great, that it had been found that burners, suited for the highest power of gas produced under the oil system, seriously affected the light when the poorer gas was supplied to them. He thought the Author was mistaken in putting down the cost of gas made in the small apparatus at Broadness at 10*s.* per 1,000 cubic feet. His experience would lead him to put it down at a much higher figure. He was informed by Mr. William Watson, the Managing Director of the City of Dublin Steam Packet Company, which used compressed oil-gas in its steamers, and manufactured it for that purpose at Holyhead, that the cost was practically about 20*s.* per 1,000 cubic feet. He believed it would be much better, for all the purposes mentioned by the Author, to compress ordinary coal-gas, which was much cheaper and more easily obtained than oil-gas. The same illuminating power would be attained in the lanterns of buoys and in railway-carriages by the use of suitable burners. For example, the new incandescent gas-burners, which largely depended for their luminosity on the heat of the gas by which they were made incandescent, and not on the illuminating ingredients of that gas, would give a far steadier and more effective light than the jets described by the Author. With respect to the Ailsa Craig lighting apparatus, he considered the method of obtaining good burning gas at that station, namely, making gas from oil and then diluting it with an admixture of common air, a clumsy and extravagant mode of procedure. He believed most gas engineers of experience would agree in this conclusion, and would also condemn the system at Ailsa Craig, of conveying air compressed to 75 lbs. pressure per square inch by pipes from one end of the island to the other; when it would have been practicable to have supplied the compressed air to the fog-signalling apparatus at each of the two lighthouses, and thus have avoided the risk of leakage and other disadvantages of sending compressed air so long a distance, and on an island so difficult of approach as that of Ailsa Craig. **Mr. Wigham.**

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17 April, 1888.

GEORGE BARCLAY BRUCE, President,
in the Chair.

The discussion upon the Paper, by Mr. Arthur Ayres, on "Compressed Oil-gas and its applications," occupied the whole evening.